REPORT

on the review of

PROPOSED ENVIRONMENTAL STANDARDS

FOR THE

MANAGEMENT AND DISPOSAL OF

SPENT NUCLEAR FUEL, HIGH-LEVEL

AND TRANSURANIC RADIOACTIVE WASTES

(40 CFR 191)

by the

High-Level Radioactive Waste Disposal Subcommittee
Science Advisory Board
U.S. Environmental Protection Agency

January 1984

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

FEB 17 1984

OFFICE OF
THE ADMINISTRATOR

Mr. William D. Ruckelshaus
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Dear Mr. Ruckelshaus:

In January of 1983, the Science Advisory Board was asked to review the Agency's proposed environmental standards for the management and disposal of spent nuclear fuel, high-level and transuranic radioactive wastes (40 CFR 191). We have completed our review of the proposed standards, and are pleased to forward to you our report, which has been reviewed and approved by the SAB Executive Committee.

The High-Level Radioactive Waste Disposal Subcommittee received the technical basis of the proposed standards for review after they had been published in the Federal Register and after both risk assessment and risk management decisions had been made and incorporated into the proposed standards. As charged, the Subcommittee concentrated its review on the scientific and technical issues. However, given the timing of its review in the rulemaking process, the Subcommittee found it virtually impossible to separate scientific and technical evaluations from matters of policy, since they are so interdependent. Our consideration of and recommendation to relax the societal objective (1000 cancer deaths in 10,000 years) by a factor of ten exemplifies this point. In any event, as responsible scientists and concerned citizens we feel it is essential that we provide you with a comprehensive report of our findings.

Our job has, in no small way, been greatly helped by the cooperation and assistance we have received from the Office of Radiation Programs, and it has been a pleasure to work with them. If I can answer any questions, or should you wish further review, I would be pleased to brief you on the contents of the Subcommittee's conclusions and recommendations.

Sincerely,

Herman E. Collier, Jr.

Herman E. Collier, Jr.
Chairman, High-Level
Radioactive Waste
Disposal Subcommittee

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This report has been written as a part of the activities of the Agency's Science Advisory Board, a public advisory group providing extramural scientific information to the Administrator and other officials of the Environmental Protection Agency. The Board is structured to provide a balanced expert assessment of scientific matters related to problems facing the Agency. The contents do not necessarily represent the views and policies of the Environmental Protection Agency.

SECTION I

HIGH-LEVEL RADIOACTIVE WASTE DISPOSAL SUBCOMMITTEE

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SECTION II

EXECUTIVE SUMMARY

The High-Level Radioactive Waste Disposal Subcommittee (HLRW) of the Executive Committee of the Science Advisory Board (SAB) has completed an extensive review of the scientific and technical basis for EPA's proposed rule for the disposal of high level radioactive wastes, the highlights of which are presented in this summary.

Technologies now exist for the disposal of such wastes, and standards adopted for them should strike an appropriate balance between conservatism and practicality. Overall, the Subcommittee is confident that, consistent with the intent of this standard-setting program, the job of disposing of high-level radioactive waste can be achieved with reasonable assurance for the well-being of present and future generations.

The Subcommittee supports the general form of the proposed standards, including (a) the use of a societal objective as an upper bound of acceptable health (cancer and genetic) effects, (b) the focus on performance standards in terms of release limits rather than individual exposures, (c) the reference level of the initial 10,000 year time frame applicable to both the societal objective and the release limits, (d) the use of a probabilistic approach, and (e) the use of qualitative assurance requirements, as modified by the Subcommittee, but issued as Federal Radiation Protection Guidance to other Federal agencies in lieu of inclusion in the proposed rule.

The Subcommittee, while accepting the general form of the proposed standards, recommends several changes in the standards and improvements in the supporting methodology. The principal recommendations are highlighted in the following summation. A more comprehensive and detailed presentation of these and other major recommendations can be found in Section IV, Major Findings and Recommendations.

A. The Standard

1. <u>The Subcommittee recommends that the release limits specified in Table 2 of the proposed standards be increased by a factor of ten, thereby causing a related ten fold relaxation of the proposed societal objective (population risk of cancer).</u>*

* Two members of the Subcommittee, Dr. Lash and Dr. Giletti, dissent from this view. They believe that the Office of Radiation Programs' more stringent standard is justified and can be met by sufficient numbers of proposed disposal sites.

The Subcommittee notes that the proposed release limits are directly related to the societal objective of not exceeding 1,000 deaths in 10,000 years, and thus, compliance with this recommendation carries with it a related ten fold increase in the societal objective. The relaxation of the release limits is, in the Subcommittee's opinion, justified for the following reasons. First, the proposed release limits in Table 2, and therefore the proposed societal objective, are considerably more stringent than those standards generally required or adopted in today's society (see for instance Table A on page 12 of this report). Second, in addition to the fact that some of the cancer deaths which might result from these releases are calculated using conservative assumptions that probably overestimate the number, some of these deaths would have resulted at least in part from the unmined ore from which the wastes were subsequently generated, and thus are substitutional rather than additional in nature. Third, the Subcommittee believes that the compounding of conservatism by EPA in the choice of probabilities and specific model parameters used throughout the analysis is not warranted.

EPA should also clarify the analytical framework that forms the basis for the limits in Table 2 of the proposed standards. The Subcommittee believes that such clarification will help to establish clearly the relationship between the release limits and the societal objective, and will facilitate future amendments to the standard as knowledge increases regarding radiation health effects or radionuclide migration in the biosphere.

Note: In Section IV, #7(Models) and #13(Geochemical Data), the Subcommittee has recommended that EPA make certain specific changes and corrections to their predictive models. Some of these changes will result in changes to the release limits for individual radionuclides given in Table 2 of the proposed standards, and will be separate from the ten-fold change in the release limits recommended above. The Subcommittee believes that the changes in the release limits, resulting from the changes to the predictive models, are independent of and would not lead to additional modification to the proposed societal objective beyond the ten fold increase discussed above.

B. Uncertainty and the Standard

1. We recommend that the probabilistic release criteria in the draft standard be modified to read "analysis of repository performance shall demonstrate that there is less than a 50% chance of exceeding the Table 2 limits, modified as is appropriate. Events whose median frequency is less than one in one-thousand in 10,000 years need not be considered."

2. We recommend that use of a quantitative probabilistic condition on the modified Table 2 release limits be made dependent on EPA's ability to provide convincing evidence that such a condition

is practical to meet and will not lead to serious impediments, legal or otherwise, to the licensing of high-level-waste geologic repositories. If such evidence cannot be provided, we recommend that EPA adopt qualitative criteria, such as those suggested by the NRC.

The Subcommittee believes that the modified probabilistic criteria will make the proposed standards more practical to apply without undue, time-consuming disagreements. Further risk studies need to be performed and subjected to systematic, critical evaluation in order to establish a more acceptable probabilistic basis for the standard.

C. The Time Frame - 10,000 years and Beyond

1. We recommend that EPA retain the 10,000-year time period as the basis for determining the adequacy of repository performance. We believe that use of formal numerical criteria limited to this approximate time period is a scientifically acceptable regulatory approach.

2. We recommend that the process of selection of sites for disposal systems also take into account potential releases of radioactivity somewhat beyond 10,000 years. Particular attention should be focused on potential releases of long-lived alpha- emitting radionuclides and their decay products.

Although the selection of a time frame is in large part arbitrary, we endorse EPA's choice of 10,000 years. Modeling and risk assessments for the time periods involved in radioactive waste disposal require extension of such developing techniques well beyond usual extrapolations; however, the extension for 10,000 years can be made with reasonable confidence. Also, the period of 10,000 years is likely to be free of major geologic changes, such as volcanism or renewed glaciation, and with proper site selection the risk from such changes can be made negligible. Potential radionuclide releases will not stop with 10,000 years, however, but may continue in amounts equal to or exceeding those estimated for the initial period.

The degree of confidence with which impacts can be modeled much further in the future is much less certain. We do not recommend detailed modeling calculations regarding post-10,000 year releases, but estimates should be made, and should be considered as factors in disposal site selection.

D. Population vs. Individual Risk

1. We recommend that EPA retain the use of a population risk criterion as the measure of performance for the proposed standards.

We find that an approach employing individual dose limits, i.e., considering some "maximally exposed individual" or alternatively some "average exposed individual" would, in practice, make the standard difficult to meet with high assurance for very long times, and that use of a population risk approach is more practical. In our view, however, it is important that for the first several hundred years residents of the region surrounding a repository have very great assurance that they will suffer no, or negligible, ill effects from the repository. For longer periods, we believe that EPA should rely on the existence of continuing requirements similar to its current drinking water standards to protect groups of individuals.

E. Coordination of Policies and Standards

1. We recommend that EPA initiate action within the Federal Government for the establishment of an interagency council to coordinate the development of high-level radioactive waste disposal policy, standards, and regulatory practices and to serve as a forum for exchange of scientific and technological information.

Several Federal agencies are involved in the process of establishing radiation protection policies, standards and operational requirements governing the disposal of high-level radioactive wastes, including EPA, NRC, DOE and DOD, together with states, appropriate entities of Congress and the judiciary. Overlapping and independent authorities and responsibilities exist under present laws. Conflicting terminology and standards exist, e.g., the definitions of high-level and other radioactive wastes. Coordination of Federal policies and practices is essential to the U.S. high-level radioactive waste disposal program. Success of the program will depend on extensive interaction and agreement among the appropriate Federal agencies. While the lead in coordination could be appropriate for the NRC or DOE, the Subcommittee feels that the obligation for achieving mutual interaction more appropriately belongs to the EPA under its authority to issue environmental standards and Federal Radiation Protection Guidance.

F. Research Needs - A Matter of Priority

1. We recommend that EPA support, or encourage other agencies to support, continuing research in technical areas where major uncertainties still exist, particularly in the biological effects of radiation, the geochemical transport of radionuclides, and the characterization of rock-mass deformation.

The Subcommittee strongly endorses support of research aimed at diminishing or clarifying as many of these uncertainties as can be attacked with some hope of resolution. The research, although expensive, could bring about a substantial reduction in the overall cost of the disposal system.

G. Responses to Original Subcommittee Charge

At the time of the Subcommittee's formation, it was directed, by the Executive Committee of the Science Advisory Board, to address six

(6) principal issues. Although a brief response to each charge is presented here, the charges are broad in scope and the Subcommittee's review of them generated a number of more explicit and specific issues which are addressed in detail in the body of this report.

1. <u>The scientific and technical rationale behind the choice of a 10,000 year time period as the basis for assessment of disposal facility performance.</u>

This issue has been addressed in C above.

2. <u>The technical basis for the selection of the proposed performance requirements, including risk-assessment methodology, uncertainties in the data and in the analytical methods, and the estimation of premature deaths.</u>

These aspects of the analysis form the basis for the proposed standards and were areas most carefully and critically evaluated by the Subcommittee. Although the Subcommittee makes a number of recommendations regarding risk assessment, pathway and health modeling and the need for improved documentation, we believe that Office of Radiation Programs, EPA, has handled these subjects well and, furthermore, has been positively responsive to the recommendations of the Subcommittee. We think, however, that EPA has made overly conservative choices and decisions throughout the development of the technical bases supporting the standards, leading to overestimation of the long-term effect of disposal, and hence that the proposed standards are too restrictive and compliance may be difficult to verify.

3. <u>The scientific appropriateness of concentrating on disposal in geologic media.</u>

This part of the charge needed no consideration by the Subcommittee, since disposal in geologic media is mandated for at least the first two sites by the Nuclear Waste Policy Act of 1982 (PL 97-425), enacted after the charge was prepared. No member of the Subcommittee, however, disagrees with this initial approach.

4. <u>The validity of the conclusion that, under the proposed rule, the risks to future generations will be no greater than the risks from equivalent amounts of naturally occurring uranium ore bodies.</u>

In reviewing this conclusion, we found, and EPA acknowledged, that the comparison is uncertain because of the extreme variability of uranium ore bodies. The Subcommittee thinks that the conclusion is valid in a very general way, if suitably qualified, but feels that it is unwise and not scientifically defensible to use the unmined ore as the only reference for comparison. We recommend that the comparison be extended to include the radioactivity of natural waters and the ambient radiation in the natural environment.

5. <u>The adequacy of the economic analysis</u>.

The Subcommittee considers there are significant shortcomings in the economic analyses supporting the proposed standards. Since the management, storage, and disposal of high-level waste is a multi-billion dollar venture, we believe that the shortcomings are important and should be remedied. It is noteworthy that, even though the savings associated with individual choices may seem relatively insignificant, the absolute costs are so large that even small percentage savings are worthwhile. The high absolute costs appear to be relatively independent of the proposed standard, and simply reflect the decision to use deep mined geologic disposal sites with multiple barriers. Thus, appreciable savings are not likely to be realized in terms of basic cost by relaxation of the standards. However, the cost of demonstrating compliance may be very high, and cost reductions that may be achieved by sophisticated compliance demonstrations could be substantial.

We recognize the need for cost/benefit analyses, using the best available data, but we note that a precise economic analysis will not be possible or meaningful until it is performed upon an actual repository at a specific site.

6. <u>The ability of the analytical methods/models used in the analysis to predict potential releases from the disposal facility and their resultant effects on human health. Included would be an evaluation of the model's ability to deal with uncertainty and the confidence, in a statistical sense, that the model predictions are adequate to support selection of projected performance requirements</u>.

In general, EPA's analytical methodology and modeling used throughout the development of the generic repository's performance, including releases and subsequent cancer deaths, are deemed to be conservative. The Subcommittee makes several suggestions for specific improvements and updating. We emphasize that modeling, including the evaluation of uncertainty and confidence therein, is an emerging and developing technique. Adding to the uncertainties implicit in a techique that is still under development are the multitude of poorly known factors associated with the extrapolation in time to 10,000 years and beyond, and the problem of securing public acceptance of the standard. We believe, nevertheless, that the EPA's effort, modified as recommended by this report, will fulfill the intent of the Nuclear Waste Policy Act of 1982.

SECTION III

INTRODUCTION

Background

Fissioning of nuclear fuel in nuclear reactors creates a small quantity of highly radioactive materials, which is retained in the spent fuel elements when they are removed from the reactor. If the fuel is then reprocessed to recover unfissioned uranium and plutonium, the concentrated radioactivity goes into acidic liquid wastes that will later be converted into solid forms. These liquid or solid wastes from reprocessing spent nuclear fuel, or the spent fuel elements themselves if they will be disposed of without reprocessing, are called "high-level wastes."

Although high-level radioactive wastes are produced in quantities that are small relative to other chemical wastes, their proper management and disposal are important because of the inherent hazards of the large amount of radioactivity they contain. Under authorities established by the Atomic Energy Act and transferred to the U.S. Environmental Protection Agency by Reorganization Plan No. 3 of 1970, and reiterated by the Nuclear Waste Policy Act of 1982 (PL 97-425), EPA is proposing generally applicable environmental standards for the management and disposal of spent reactor fuel, high-level wastes derived from reprocessing spent fuel, and wastes containing chiefly long-lived radionuclides of elements heavier than uranium (transuranic (TRU) wastes). The proposed rule is appended to this report (Appendix B).

The objectives of the proposed standards are to limit the risks to both present and future generations and to adequately protect the public from harm caused by management and disposal activities related to these radioactive wastes. Separate standards were developed for those activities related to waste management and storage operations preparatory to disposal (Subpart A) and for the long-term performance of disposal systems (Subpart B).

Science Advisory Board Review

The Science Advisory Board (SAB) was asked, in January 1982, to review the scientific and technical basis of EPA's proposed rule. A Subcommittee of the Executive Committee, chaired by Dr. Herman E. Collier, Jr., was formed to accomplish this review. Because the release of the proposed standards was delayed until December 19, 1982, the Subcommittee began its review on January 18, 1983. At that time, EPA requested that the Subcommittee concentrate its review on Subpart B of the proposed standard and identified six issues, listed in the previous section, for the Subcommittee's consideration.

The Subcommittee organized itself for the review into seven (7) Subgroups, which are listed below (Chairmen are listed first):

A. Risk Assessment (Dr. Okrent, Dr. Budnitz, Mr. Culler, Dr. Parker).

B. Environmental Pathways (Dr. Kaye, Dr. Boecker, Dr. Lash, Dr. Parker).

C. Geochemistry (Dr. Giletti, Mr. Culler, Dr. Davis, Dr. Krauskopf).

D. Biological Effects (Dr. Neel, Dr. Boecker, Dr. Kaye).

E. Assurance Requirements (Dr. Lash, Dr. Budnitz, Dr. Krauskopf, Dr. Okrent).

F. Engineering and Economics (Dr. Parker, Dr. Budnitz, Mr. Culler, Dr. Davis, Dr. Fairhurst).

G. Subpart A Requirements (Dr. Krauskopf, Dr. Fairhurst, Dr. Giletti, Dr. Kaye, Dr. Lash).

The Subcommittee, in the course of its review, held nine (9) meetings and many other informal subgroup meetings. At the Subcommittee meetings (for which minutes and verbatim transcripts are available in the offices of the Science Advisory Board) there was extensive comment by the Office of Radiation Programs, EPA, representatives of DOE, NRC and their contractors, and others. Only a few comments came from the general public, although the meetings were open and advertised in the Federal Register. At its final meetings, the Subcommittee formally adopted its major findings and recommendations, which were based primarily on the Subgroup reports. Deliberations focused on using the Subcommittee's collective wisdom, but votes were taken on each of the recommendations as worded in this report. These recommendations represent majority views, therefore, and do not necessarily reflect the views of all members.

Acknowledgements

The Subcommittee commends the EPA Office of Radiation Programs for doing a generally comprehensive and scientifically competent job in developing the technical analyses supporting the proposed standards. The Subcommittee also acknowledges the outstanding cooperation and support provided by the ORP staff and particularly by Mr. Dan Egan, project officer for the proposed standards.

The Subcommittee also acknowledges the generous assistance of Mr. Robert Catlin of the Electric Power Research Institute and Dr. David C. Kocher of Oak Ridge National Laboratory, who provided data and analytical assistance, and who participated actively in the Subcommittee's deliberations.

SECTION IV

MAJOR FINDINGS AND RECOMMENDATIONS

The findings and recommendations which follow are grouped under 17 major topics. The discussion of each topic includes one or more underlined recommendations, and for several topics underlined findings and endorsements are included also. Brief explanatory paragraphs and references to relevant Subgroup reports follow the underlined material.

A. Uncertainty and the Standard

1. We recommend that EPA adopt a standard which provides adequate protection with regard to societal effects; which can be met technically for at least some known technological approaches; on which it will be practical for NRC to make a favorable finding with reasonable assurance; and which does not needlessly induce or lend itself to long controversy and delay in arriving at a decision in the regulatory framework and in the courts.

2. We believe that repository designers will find it quite difficult and perhaps excessively expensive to demonstrate with reasonable or high assurance that the levels of protection sought by EPA in the draft standard have been met.

3. We find that the "release limit" approach for expressing the level of protection required of a repository is a satisfactory way of fulfilling EPA's standard-setting mandate, and should be retained by EPA.

4. We recommend that the release limits in Table 2 of the proposed standard be increased by a factor of 10 which will result in a corresponding relaxation of the societal objective (population risk of cancer) by a factor of 10.

5. We recommend that the probabilistic release criteria in the draft standard be modified to read "analysis of repository performance shall demonstrate that there is less than a 50% chance of exceeding the Table 2 release limits, modified as is appropriate. Events whose median frequency is less than one in one-thousand in 10,000 years need not be considered."

6. We recommend that use of a quantitative probabilistic condition on the modified Table 2 release limits be made dependent on EPA's ability to provide convincing evidence that such a condition is practical to meet and will not lead to serious impediments, legal or otherwise, to the licensing of high-level-waste geologic repositories. If such evidence cannot be provided, we recommend that EPA adopt qualitative criteria, such as those suggested by the NRC.

7. We find that an approach to the EPA standard employing "individual dose limits" (considering some "maximally exposed indi-

vidual," or alternatively some "average exposed individual") would in practice make the standard difficult to meet with high assurance for very long times for any repository concept currently under active consideration. However, we recommend that for the first 500 years, the EPA standard embody an extremely low likelihood that increases in radioactivity approaching the limits allowed by the EPA drinking water standards will occur in potable well water drawn from any well adjacent to the site of the repository. For longer time periods, we recommend that EPA rely on the assumption that standards similar to the present drinking water standards will exist to protect groups of individuals.

The available risk studies for postulated repositories are subject to very large uncertainties. Nevertheless, it appears that for most repository technologies and site types currently under active consideration by DOE there is a reasonable likelihood that the levels of protection sought by EPA in its proposed standards can be met. However, demonstration of this accomplishment with high assurance may prove to be difficult.

As shown in the accompanying Table A, the proposed standards lead to levels of protection much more stringent than those generally required or adopted in today's society; in addition, the proposed standards are far more stringent than those imposed on chemical wastes. The number of cancer deaths which might result from these releases are calculated using conservative assumptions that probably overestimate the number. This overestimation is compounded by conservative choices for probabilities and specific model parameters throughout the analyis. Furthermore, at least some of the cancer deaths would have resulted anyway from the radioactivity in the unmined ore from which the waste was subsequently derived. Thus, we conclude that a ten-fold increase in the release limits, which will result in a corresponding ten-fold increase in the societal objective (not more than 1,000 calculated cancer deaths in 10,000 years) would still provide adequate protection, and that the risks would still be extremely low. The relaxation of the release limits is recommended with the proviso that, based on the studies available to it up to the time be built and operated with reasonable assurance that the EPA standard has been met. This proviso should be subject to the constraint that the criteria for disposal of high-level waste remain substantially more stringent as to societal risks than are currently accepted by EPA for hazardous chemical wastes or uranium mill tailings.

There was disagreement in the Subcommittee on Recommendations b), d), and e). A majority believes that highly conservative estimates have been made in the models for release of nuclides from the repository to the accessible environment. Dr. Lash and Dr. Giletti believe that more realistic models, based on site-specific cases, will demonstrate that sufficient sites can be found for which it can be demonstrated with high confidence that the proposed release limit standards can be met. They feel that no increase in either the release limits or the implied potential premature cancer deaths limits is warranted.

TABLE A

NUMBER OF POSSIBLE CANCER CASES DUE TO IONIZING RADIATION[1]

ORIGIN	NO. OF CASES PER YR.[2]	NO. OF CASES PER 10,000 YR.[2]
High-level Rad. Waste Disposal[3]	up to 0.1	up to 1,000
Uranium Mill Tailings[4]		
- Unprotected†	3	30,000*
- Protected (covered, etc.)	0.03	300*
Indoor Air Pollution		
- Residential Exposure[5]	1,000 to 20,000	10,000,000 to 200,000,000*
- Residential Weatherization (added cases)[5] (Nero Estimate)	250 to 5,000	2,500,000 to 50,000,000*
- Residential Weatherization (added cases)[6]	10,000 to 20,000	100,000,000 to 200,000,000*
Background Radiation[7]	3,000 to 4,000	30,000,000 to 40,000,000

[Cancer Deaths (U.S.)[8] (all causes) 430,000]

Notes: [1] These numbers are all calculated on the same basis using a linear non-threshold dose response model, as noted on pp. A-7-3 and A-7-4 of this report. The linear non-threshold model involves a high degree of speculation, and the resulting values have little merit as absolute indicators of the numbers of biological effects that may occur. It has been used here to provide a framework within which relative risks from various radiation exposure situations can be compared.

[2] Assuming constant U.S. population and culture - numbers with (*) are extrapolated from annual values.

[3] EPA proposed rule 40 CFR Part 191 (December 1982) number per 100,000 MTHM high-level radioactive waste repository.

[4] NRC (October 1980). "Uranium Mill Licensing Requirements: Final Rules," Federal Register, 45, No. 194, 65521-65538. Radon inhalation exposures.

TABLE A (Continued)

[5] Nero, A.V. "Indoor Radiation Exposures From ^{222}Rn and Its Daughters: A View of the Issue," Health Physics, 45, No.2, (August 1983), 277-288.

[6] EPA Report EPA 520/4-78-013 (revised printing, July 1979)

[7] NAS/NRC, The Effects on Populations of Exposure to Low Level of Ionizing Radiation (November 1972) - (1972 BEIR Report).

[8] American Cancer Society, Cancer Facts and Figures - 1982, 1981.

† Does not include health effects from water pathways.

As noted in Table A, large uncertainties must be anticipated in risk estimates covering 10,000 years. The NRC, as well as several responsible scientific reviewers, have questioned the workability of the quantitative probabilistic portion of the proposed EPA release standard. The proposed revisions to the EPA standard may make it more practical to apply without undue, time-consuming disagreement. EPA needs to perform more risk studies, and have these studies subject to sufficient, systematic critical evaluation in order to choose an acceptable probabilistic basis for its standard. Although we strongly affirm the validity of EPA's probabilistic approach, if EPA cannot have high confidence in the adequacy and workability of a quantitative, probabilistic standard, we recommend use of qualitative criteria, such as recommended by NRC.

We support the use of a population risk criterion. We believe it is impractical to provide absolute protection to every individual for all postulated events or for very long periods. On the other hand, in our view it is important that for the first several hundred years residents of the region immediately outside the accessible environment have very great assurance that they will suffer no, or negligible, ill effects from the repository. For longer periods, we believe that EPA should rely on the existence of standards similar to its current drinking water standards to protect groups of individuals.

(See Risk Assessment Subgroup report, Appendix A-1; Recommendations 9 and 10, Environmental Pathways Subgroup report, Appendix A-2; Finding 1, Engineering/ Economics Subgroup report, Appendix A-6 and Recommendation 5, Biological Effects Subgroup report, Appendix A-7.)

B. <u>The 10,000-Year Time Period</u>

1. <u>We recommend that EPA retain the 10,000-year time period as the basis for determining the adequacy of repository performance. We believe that use of formal numerical criteria limited to this approximate time period is a scientifically acceptable approach.</u>

2. <u>We recommend that the process of selection of sites for disposal systems also take into account potential releases of radioactivity somewhat beyond 10,000 years. Particular attention should be focused on potential releases of long-lived alpha-emitting radionuclides and their decay products.</u>

For certain long-lived radionuclides likely to be placed in repositories (and their decay products), the impact of release on the accessible environment is likely to be greater in the period beyond 10,000 years than in the period prior to 10,000 years. Nevertheless, especially considering the uncertainties, we believe that the <u>overall</u> performance is likely to be adequately understood by using analytical models that extend 10 millennia into the future. The degree of confidence with which impacts can be modeled much further in the future is poor. Thus we find that assurance of adequate repository performance can be best attained by concentrating analytical and repository design effort at achieving satisfactory performance through the first 10,000 years. There will be no abrupt change, however, in release effects at the end of 10,000 years, and assurance is needed, particularly in the selection of repository sites, that effects in the more distant future will not be greatly increased. Therefore, estimates of releases and release effects beyond 10,000 years should be made as part of the process of site selection. The intent of recommendation B.Z. is not to require an elaborate quantitative modeling study of releases beyond 10,000 years, but only to point out one of the important considerations that should guide the choice of repository sites from among those nominated by DOE in accordance with the Nuclear Waste Policy Act.

(See Recommendations B-2, C-1, C-2, Risk Assessment Subgroup report, Appendix A-1; Recommendation 7, Assurance Requirements Subgroup report, Appendix A-4; and Recommendation 2, Geochemistry Subgroup report, Appendix A-5.)

C. Unmined Uranium Ore Reference

1. We recommend that EPA downplay the comparison of repository releases with unmined uranium ore bodies by expanding the comparison to include the radioactivity of natural waters and ambient radiation in the natural environment.

2. We recommend that EPA emphasize more strongly that somatic and genetic effects resulting from repository releases that meet EPA's proposed standard are at least in part substitutional effects, rather than additive to those expected from the unmined ore.

EPA has estimated that the potential releases of radioactivity from repositories for high-level and TRU wastes will be less than releases from the undisturbed uranium ore from which the waste was derived. Qualitatively, ore-body and repository risks may be compared in a very general way. However, the Subcommittee concludes that the natural variability among ore bodies and the large uncertainties in the data derived from them preclude an accurate comparison of a generic repository with a hypothetical ore body. Furthermore, a broader appreciation of the performance standard will be gained if the comparison is extended to include the radioactivity of natural waters together with other natural and man made sources of ambient radiation.

Despite the uncertainties in quantitative comparisons with unmined ore, the somatic and genetic effects that may be produced by releases from a repository are at least in part equivalent to effects that would have been produced by the ore had it never been mined. Thus radiation from high-level waste in a high-level repository should not be considered entirely as an addition to natural environmental radiation, but in part as a substitution for radiation that would have reached the biosphere anyway.

(See Table 1 and Recommendation D-1, Risk Assessment Subgroup Report, Appendix A-1.)

D. Biological Effects

1. We recommend that EPA, in their calculations, drop the ambiguous terminology "health effects" when specific reference to somatic (cancer) and/or genetic effects can be made.

2. We accept EPA's use of the linear non-threshold model for estimating health risks.

3. We recommend that EPA consider the genetic effects to all future generations, rather than limiting them to the first generation.

4. We recommend that EPA consider using the concept of effective dose equivalent in setting a dose limit in Subpart A of the proposed standard.

The term "health effects" is often used when actually referring to cancer mortality. While cancer-related effects may predominate over genetic related effects, it is important to recognize that both may occur, and more specific language is therefore needed.

Although other models for estimating health risk are available and despite uncertainties about the validity of the linear non-threshold model in particular, this model is generally accepted for radiation protection purposes by professionals as the conservative model of choice.

Somatic effects have been appropriately calculated on a generation-by-generation basis. Genetic effects differ, however, in that they cumulate as a result of transferral from one generation to another. Even though genetic effects are commonly less numerous and less serious than somatic, it is possible for the accumulated harm from genetic effects in any generation to be as great as that from somatic effects over the passage of 10,000 years. To make an accurate comparison with somatic effects, it is necessary to compute genetic effects over all generations within a given time period.

In Subpart A of 40CFR191, EPA specifies dose limits of 25 mrem/yr to whole body, 75 mrem/yr to the thyroid, or 25 mrem/yr to any other organ. These limits are the same as those in 40CFR190, and they are based essentially on the critical organ approach to radiation protection. In Subpart B, however, the radionuclide release limits are derived using a sum of dose equivalents to different body organs weighted by the stochastic risk factors for each organ. This is the same approach as the effective dose equivalent described in reports of the

International Commission on Radiation Protection (ICRP 26 and 30). Thus, the two approaches to calculating doses in Subparts A and B are clearly not consistent.

(See Recommendation 1, Environmental Pathways Subgroup report, Appendix A-2; Recommendation 3, Subpart A Subgroup report, Appendix A-3; and Recommendations 1, 2, 4, and 6, Biological Effects Subgroup report, Appendix A-7.)

E. Assurance Requirements

1. We recommend that the assurance requirements, as amended by this report, be submitted as a Federal Radiation Protection Guidance document in support of the EPA rule package.

2. We recommend that EPA delete the assurance requirement for prompt disposal of high-level and transuranic wastes.

3. We recommend that use of the concept of "as small (low) as reasonably achievable" (ALARA) be limited to the consideration of the geologic characteristics of sites nominated in accordance with the Nuclear Waste Policy Act.

4. We recommend that the assurance requirement for use of multiple barriers be revised to give more emphasis to the system as a whole, rather than to the performance of each barrier acting alone. Barriers should be designed so that they complement each other and help to compensate for unexpected failures.

5. We recommend that EPA limit the time period during which repository designers may take credit in their analyses for reliance upon active institutional controls to a period of no more than 100 years, and that suitable surveillance be required during that period. Surveillance techniques should not compromise the integrity of the repository. The definition of active institutional controls should be changed so that guarding, maintaining, and taking appropriate remedial actions are all required.

6. We recommend that EPA not preclude consideration of a potential repository site because natural resources are at or near the site, but rather should note that the presence of such resources is a highly unfavorable factor which should be included in the site evaluation.

7. We recommend that assurance requirement (g) on retrievability of waste be deleted.

The question of the appropriateness of EPA's specifying assurance requirements gave rise to considerable division of opinion among Subcommittee members. In particular, it was noted that these requirements pertain to implementation of the standard and not to standard-setting, and thus may be outside EPA's and the Subcommittee's domain. Others considered that the requirements were highly supportive of the standard and enhanced public acceptance of the standard and subsequent regulations. Several members believe that the assurance requirements, if included in the standard itself, would encourage litigation or other delays by intervenors. We understand that submission of these requirements as Federal Radiation Protection Guidance will convey their importance to the standard, avoiding the possible conflicts noted.

There is a requirement in the Nuclear Waste Policy Act for DOE to assess the advantages of long-term storage. Temporary storage for 20-30 years is accepted practice to allow spent fuel to "cool down." It may also be advantageous for ease of computation, lesser disturbance of the geologic environment, etc., to extend the cooling period. The prompt disposal requirement in the proposed standards appears inconsistent with these considerations, and should be reexamined accordingly.

The ALARA concept can be interpreted in two ways, one philosophical and the other applied. Philosophically it is a "motherhood and apple pie" statement which prescribes the use of common sense in deciding alternatives in the development of the repository. As applied, ALARA could become the rationale for spending additional money and time in the building of the repository, and could also be a basis for protracted litigation. We believe that the release limits set forth in the standard are already so low that any design calculated to satisfy them will adequately protect the environment, and an added ALARA requirement is unnecessary. Such a requirement might serve a useful purpose, however, as one basis for choosing a repository site from a number of possible candidates.

The present wording of assurance requirement (c) that "each barrier shall separately be designed to provide substantial isolation" has the implication that any one barrier acting alone should enable the repository to comply with the proposed standard. We think that it is more important that the system of barriers as a whole be designed to compensate for the unexpected weakness or failure of one or two members.

We would limit the period for which the repository designer should be allowed to take credit for active institutional controls to no more than 100 years. A monitoring system designed to test predictions of system behavior during the time of active institutional controls, however, would help to reassure the public and, in the unlikely event of appreciable adverse developments, would permit remedial measures to be taken promptly. Surveillance should consist of relatively simple monitoring techniques to avoid initiating or enhancing release pathways from the repository. The presence of mineral resources at a site is a highly unfavorable characteristic, but it should not automatically preclude use of the site. EPA should require DOE to analyze carefully the possible consequences of nearby mineral resources, weighing them against other site characteristics which may be strongly favorable.

(See Assurance Requirement Subgroup report, Appendix A-4)

F. Accessible Environment

1. We recommend that EPA extend the definition of "accessible environment" to include major sources of potable groundwater that are beyond the controlled area, as defined by NRC in 10CFR60 (Technical Criteria for Disposal of High-Level Radioactive Waste), and are more than two (2) kilometers in a horizontal direction from the original location of the radioactive wastes in a disposal system.

This consideration is to note the specific importance of potable groundwater as a much needed resource, particularly in the western areas of the country. Protecting this resource, as reflected by this position, indicates that we feel the importance of potable groundwater supplies will not diminish in the future and may become even more important.

G. Models

1. We find that in their analyses of releases to the accessible environment, EPA has frequently made modeling assumptions and parameter estimates which are conservative. These values were combined in the models, leading to computed releases to the accessible environment that are probably overestimated. While perhaps less conservative, this bias was also carried through in the en-environmental pathways analyses.

2. We recommend that EPA define clearly all models used in their analyses, if not already so documented, and ensure that state-of-the-art information is used.

3. We recommend that EPA, in their environmental pathways modeling, re-evaluate the assumed fraction of activity transported to the land surface via irrigation and make provision in the models for recycling activity leached from soils and returned to the rivers.

4. We recommend that the environmental pathways models be modified to incorporate the time dependence of resuspended activity in soils and of external ground-surface exposure.

5. We recommend that EPA improve the evaluation of uncertainties inherent in all aspects of the analyses, including movement to the the accessible environment, the modeling of exposures through various environmental pathways, and conversion of doses to somatic and genetic effects.

We endorse EPA's use of conservative parameter estimates when reliable data are not available and mean or median values when good data are available. We also endorse the use of conservative modeling assumptions. EPA should document carefully each conservative estimate or assumption, however, and where possible, express parameter values as single values together with the uncertainty associated with those values.

The computations of environmental dose commitment used in support of the proposed standards were made several years ago with dosimetric approaches and computer models available at that time. Some improvements have been made in dosimetry parameters and calculational methods in the intervening years. The current EIS and other documents supporting the proposed standards contain health risk factors for different body organs, expressed as the risk of cancer (or genetic effects for gonad irradiation) per rem of absorbed dose equivalent. This list is an accurate reflection of the current knowledge regarding the relative risks of absorption of radiation by different tissues. However, the numerical values are not directly traceable to any particular set of risk factors as presented in reports by advisory bodies such as the NAS Committee on Biological Effects of Ionizing Radiation (BEIR) or the ICRP. We recommend that all health risk factors be referenced to appropriate advisory bodies and their respective reports.

In their environmental pathways modeling, EPA has assumed that 50% of surface waters are used for irrigation. Several sources indicate that the actual percentage is much lower. In their resuspension model, EPA assumes that resuspension occurs from the entire root zone. Resuspension actually occurs, however, only from the top soil layer. The appropriate time dependence of resuspension depends on whether the soil is assumed to be undisturbed or frequently plowed.

Substantial uncertainties exist in the estimates of doses delivered to populations from specific curie releases of radionuclides from repositories. Nowhere, however, does EPA present the overall level of uncertainty in its calculations, nor does EPA compare the level of uncertainty in the pathways analyses to uncertainties in the analyses of radionuclide movement through the geosphere to the accessible environment or to the uncertainties in the conversions of doses to cancer and genetic effects in humans. An overall assessment of uncertainty in the effects of specific curie releases might be useful for evaluating the suitability of the proposed assurance requirements and in determining the values chosen for release limits to the accessible environment. (See Environmental Pathways Subgroup report Appendix A-2; General Statements in the Geochemistry Subgroup Report, Appendix A-5)

H. Dilution/Isolation

1. We recommend that dilution not be an acceptable practice to avoid the regulations for disposal of material as high-level waste,

but that it be considered as a reasonable means of converting minute quantities of high-level or TRU waste into material that can be disposed of under 10CFR61 (Licensing Requirements for Land Disposal of Radioactive Wastes).

We endorse the intent of the EPA standard to localize and isolate high-level waste in contrast to dilution and dispersion. Although supportive of isolation as noted, we are not inclined to prohibit dilution of minute amounts of waste such as those produced in research and medical practice so as to make them acceptable for shallow land burial. (See Recommendation 1, Subpart A Subgroup report, Appendix A-3).

I. Engineering and Cost Considerations

1. We recommend that EPA perform an economic analysis (benefit/cost analyses; differential costs and benefits for widely different levels of protection; and costs for alternate means of disposal) in addition to the cost analysis already presented. In making this analysis EPA should use more current cost models and data now available.

2. We recommend that EPA examine carefully the possibilities for cost savings in the waste disposal program. Though the uncertainties in the cost estimates are great, the absolute amounts involved are so large that even small percentage savings could represent substantial amounts of money.

3. We recommend that EPA consider discounted, as well as non-discounted, costs for the operational period. This will help to disclose the significance of sequencing and delays on site selection and engineering designs of repositories.

4. For a generic, deterministic study the aggregated, simple model used by EPA is adequate for a cost analysis. However, the cost for actual repositories at specific sites could diverge substantially from these generic costs.

Given the data available at that time (early 1982), the cost analysis (see draft Regulatory Impact Analysis, EPA 520/1-82-024) is reasonably comprehensive and adequate, and uses data valid in early 1982. New data, however, are now available, e.g., Waddell et al., Engel and White, Clark and Cole, and the Defense Waste Management Plan.

An economic analysis, as recommended, could help to identify the opportunities for optimizing waste management strategies, to indicate the real costs of delays, and to suggest possible cost savings etc., especially if discounted cost procedures are included.

Discounted cost procedures recognize that expenditures incurred early in repository development are of greater significance than the same amounts expended later. The relative importance of the various cost components in waste isolation could be changed drastically by the use of discounted dollars.

Finally, given the intrinsically high degree of safety of any acceptable repository, its high cost, and the uncertainties of the cost estimates, the relationship between such costs and the level of safety achieved can be shown to a limited extent only.

J. Dose Limits

1. We recommend that EPA analyze the practicality of implementing the suggested dose limits (under Subpart A) at facilities that that include operations of both the uranium fuel cycle and the management and storage of high-level wastes.

While EPA has demonstrated that the suggested limits, or even lower limits, should be attainable in normal management and storage operations, it is not clear that they are realistic at combined facilities which also include operations pertaining to the uranium fuel cycle. For such combined facilities, some deviation from the suggested limits could be allowed without endangering public health and safety.
(See Recommendation 4, Subpart A Subgroup report, Appendix A-3.)

K. Factors in Site Selection

1. No site type should be precluded on the basis of site characteristics alone. Consideration of all factors, including engineered barriers, transportation, availability of utilities and labor, etc., may lead to different choices amongst acceptable sites and isolation technologies than those dictated by site characteristics alone.

The constraints on exploration for, and selection of, geological repository sites and the associated long-term containment performance requirements have no counterparts in geological engineering experience. The distance of a repository from radioactive waste production and storage sites, possible engineered barriers, and socio-economic factors are considerations. Evaluation of all such factors may lead to a preference for sites, among those shown to be satisfactory, which might possibly be ranked below other sites on the basis of geological criteria alone.
(See Recommendation 4, Engineering/Economics Subgroup Report, Appendix A-6.)

L. Limit Standard to Mined Geologic Repositories

1. We recommend that the applicability of Subpart B of the proposed standards be explicitly restricted by EPA to disposal in mined geologic repositories.

The present wording implies that the standard is intended to cover all methods of disposal except disposal directly into ocean sediments. To avoid any implication that other methods of disposal were evaluated, and therefore to avoid foreclosing other possibilities, the standard should be limited to disposal in mined geologic media.

(See Recommendation 1, Assurance Requirements Subgroup report, Appendix A-4)

M. Geochemical Data

1. We recommend that EPA, in their generic analyses, utilize different sets of geochemical parameters for high-ionic-strength environments (such as salt) and for the much lower-ionic-strength waters expected in many other lithologies.

2. We recommend that EPA reassess the values it chose for solubility and retardation factors for Am, Sn, Sr, Cs, Tc, and Np.

3. We recommend that EPA encourage research leading to better values for solubilities and retardation factors for the nuclides listed in Table 2 of 40CFR191, plus I-129, Cm-247, Pb-210, Zr-93, and Sb-136.

The retardation by sorption of radionuclides dissolved in migrating groundwater is much lower in brines associated with salt repositories than in water associated with many other geologic formations, and two sets of geochemical parameters are needed for these two different ground-water environments.

Values used for the solubilities and retardation factors for several radionuclides need reassessing in the light of recent data. Retardation factors for Sr and Cs are particularly sensitive to variations in ionic strength, and two different values should be used for each. The solubilities for Tc and Np change enormously with slight changes in redox potential, and the possibility of much greater releases of these nuclides under slightly oxidizing conditions should be noted. Solubilities of Am compounds are especially uncertain and especially sensitive to changes in pH, and these uncertainties should be recognized.

To establish release requirements that are both safe and attainable, EPA must have sufficiently good data to make realistic estimates of the rate of transport of all important radionuclides through the various repository lithologies and possible aquifers. Available data are less than satisfactory for some radionuclides, and research is needed to narrow the uncertainties.

(See Recommendations 1, 3, and 4, Geochemistry Subgroup Report, Appendix A-5).

N. High-Level Radioactive and Transuranic Wastes Definitions

1. We recommend that EPA's definition of high-level radioactive wastes be consistent with that set forth in the Nuclear Waste Policy Act (NWPA) and coordinated with the definition used by the Nuclear Regulatory Commission (NRC).

2. We recommend that EPA check the definition of TRU waste to ensure consistency, both within EPA and among EPA, DOE and NRC.

The following is proposed for EPA's consideration.

"High-level radioactive wastes" means "(1) spent nuclear fuel if disposed of without reprocessing; (2) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations (sufficient concentrations, as a general guideline, means concentrations greater than those identified in Table 1 of the proposed standard, but some flexibility is permissible in using these limits for particular kinds of waste and particular disposal systems); (3) other highly radioactive material that the NRC, consistent with existing law, determines by rule requires permanent isolation. High-level waste may not be converted to low-level waste by dilution, except for very small amounts such as those produced in research or in medical practice."

Given the several and varied factors which currently may be used to characterize TRU wastes and the complexity associated with resolving this situation, we are not prepared to recommend a definition but urge EPA to make its definition consistent with that of other agencies and the intent of the NWPA.

(See Recommendations 1 and 2, Subpart A Subgroup report, Appendix A-3.)

O. Defense Wastes

1. We recommend that a suitable equivalency to the MTHM concept (such as one based on number of fissions) be established for defense wastes, and for some kinds of commerical wastes.

The proposed rule does not adequately address these wastes, and leaves vague the responsibilities for setting the standards for their disposal.

P. EPA's Role as Coordinator

1. We recommend that EPA initiate action within the Federal government for the establishment of an interagency council to coordinate the development of HLRW disposal policy, standards, and regulatory practices and to serve as a forum for exchange of scientific and technological information.

Several Federal agencies are involved in the process of establishing radiation protection policies, standards and operational requirements governing the disposal of high-level radioactive wastes, including EPA, NRC, DOE and DOD, together with the states involved and appropriate entities of Congress and the judiciary. Overlapping and independent authorities and responsibilities exist under present laws. Conflicting terminology and standards exist, e.g., the definitions of high-level and other radioactive wastes. The Subcommittee recommends that EPA take the initiative within the Federal government to take the lead in establishing an interagency program for the coordination of radiation protection policy and standards development relative to the disposal of high-level and other radioactive wastes. Coordination of Federal policies and practices is essential to the U.S. high-level radioactive wastes disposal program, and the Subcommittee finds success of this program highly unlikely without extensive interaction and agreement among the appropriate Federal agencies. While either the NRC or DOE could appropriately take the lead in this coordination, the Subcommittee believes that the role more appropriately belongs to the EPA under its authority to issue environmental standards and Federal Radiation Protection Guidance.

Q. Needed Research

1. We recommend that EPA support and/or encourage other agencies to support research in technical areas where major uncertainties still exist, particularly in the biological effects of radiation and the controls on geochemical transport of radionuclides.

A substantial body of research supports EPA's proposed standards, as well as the recommendations of this Subcommittee, but major uncertainties still exist in some of the basic data. The uncertainties have led EPA and the Subcommittee to adopt generally conservative positions, which may translate into undue costs. The Subcommittee strongly endorses support of research aimed at diminishing or clarifying as many of these uncertainties as can be attacked with some hope of resolution. The research, although expensive, could bring about a substantial reduction in the overall cost of the disposal system.

Three areas in which research is particularly needed, and in which new technologies might make it particularly fruitful, are the biological effects of radiation, the determination of better values for the solubilities and retardation factors which control the movement of radionuclides in various kinds of repository environments, and the long-term behavior of the repository host rock.

With respect to somatic and genetic effects at the very low dose levels involved in possible population exposures, it is necessary to extrapolate the dose-response model over several orders of magnitude beyond our current knowledge. A concerted effort should be made, using data from human subjects, laboratory animals and cellular systems as appropriate, to provide a substantial improvement in the data base. Such research would probably involve a cost which would be a small fraction of the total expenditures under discussion.

Given the strong dependence on the geological barriers, it becomes critical that transport estimates for the various repository lithologies and possible aquifers be thoroughly assessed. This assessment should include those potentially real conditions (especially for pH and oxidation potential) that extend beyond the ranges assumed in the generic models. Specifically, data are needed for solubilities and retardation factors for most of the nuclides listed in Table 2 of the proposed standard plus additional data on retardation factors for fluid interactions with a variety of appropriate and well-characterized solid media.

Most information on rock-deformation behavior used in the prediction of repository performance is based on data obtained from small-scale, short-term laboratory studies on intact rock specimens. Use of this data for calculation of the full-scale, long-term behavior of rock masses involves important simplifying assumptions of numerical and closely-interrelated physical modeling. Tests of both the large scale laboratory and in situ testing variety are needed to improve the reliability of assessment of actual repository performance.

Although much of the needed research cited cannot be completed in the short term, the Subcommittee believes that, to the extent it is possible, the results might lead to a later reconsideration of some of EPA's calculations, estimates, and subsequent decisions.

APPENDIX A

SUBGROUP REPORTS

1. Risk Assessment
2. Environmental Pathways
3. Subpart A Requirements
4. Assurance Requirements
5. Geochemistry
6. Engineering/Economics
7. Biological Effects

APPENDIX A-1

REPORT

of the

RISK ASSESSMENT SUBGROUP

January 17, 1984

Dr. David Okrent, Chairman
Dr. Robert Budnitz
Mr. Floyd Culler
Dr. Frank Parker

INTRODUCTION

1. Perspectives on Risk

It can be of value to gain a perspective on the level of risk due to geologic disposal of high level waste per the proposed EPA standard. One basis for gaining perspective on the level of safety sought by EPA in its proposed standard for the geologic disposal of high level waste is to examine a few other related aspects of societal risk.

1.1 Hazardous Chemical Waste

The Congressional Office of Technology Assessment has recently released a study entitled "Technologies and Management Strategies for Hazardous Waste Control" (March 1983). Hirschhorn and Gough summarized the review in a recent symposium at MIT and gave a strong indictment of current EPA practices. From this review and other sources (for example B. Cohen, 1981), it seems that hazardous chemical wastes pose a threat roughly on the same order as that from high-level radioactive wastes from all of our reactors and in part would remain hazardous for extremely long times. However, a hazardous chemical waste site, if it were controlled per EPA's latest standards, would have an impervious liner which might be good for 20 to 30 years, and would be designed for the 100 year flood. The owner could "walk away" from the site after about 25 years. Hence, it is reasonable to expect that such waste might be contained, 20 to 100 years on the average, if disposed of in an EPA-approved site. After that time, if not before, one could expect that the waste might move into the accessible environment.

1.2 Uranium Mill Tailings

NRC estimates imply that the uranium mill tailings, if left uncovered, but not dispersed, would result in about 3 premature deaths per year averaged over the very long term, due only to radon released to the atmosphere and inhaled. Current NRC approaches would reduce estimated fatalities by a factor of about 100. EPA has proposed the use of modified RCRA standards involving (i) impermeable liners, (ii) a complex monitoring and remedial action compliance program, (iii) no degradation of the nearest aquifer below the tailings, (iv) design for stabilization for 1,000 years, and (v) a radon release standard which requires cover thick enough to minimize human intrusion and misuse of the tailings.

The NRC staff opposes most of the EPA proposed standards as unworkable or unnecessarily stringent.

The EPA proposed standard for uranium mill tailings appears to be far more stringent than those for hazardous chemical wastes but far less stringent than that proposed for geologic disposal of high-level radioactive wastes, at least with regard to water pathways.

1.3 Indoor Air Pollution--Radon

EPA does not have any standards governing indoor air pollution, including radon. Kasperson quotes a nationwide estimate of 1,600 annual premature cancer deaths from radon exposure in buildings. Hurwitz notes that the National Commission on Radiation Protection (NCRP) has proposed to rectify the present absence of residential radiological standards by adopting a limit of two working level months per year for public exposure to radon progeny. The risk from lifetime exposure to this limit is estimated by the NCRP to be 18,200 deaths per million (or 1.8 in a 100). Nero has summarized much of this problem, and his risk estimates are compared with those for uranium mill tailings and with the proposed EPA standard for high-level radioactive waste in Table A (all for 10,000 years assuming the current U. S. population is static).

1.4 Intergenerational Risks

In general, we would prefer to avoid, whenever possible, the transfer to future generations of risks from current activities. Thus, given a hypothetical choice between two disposal schemes which pose the same costs and short-term risks, we would choose the scheme which had the lesser long-term risk. In practice, however, the choices are far less clear-cut, and selecting among alternatives involves balancing many different attributes.

With regard to intergenerational effects, there are few, if any, other major societal activities which could continue if forced to meet a standard of requiring such small risks to generations as far into the future. Such a criterion is not met for most, if any, industries, including the mining of resources. The intergenerational aspect is not met for the generation of electricity from fossil or alternative fuels. It clearly is not met by our chemical industry.

Should it be? Should there be no increase in risk to future generations at the cost of deprivation, even premature death, today? Need there not be a balance among benefits and costs, including costs to the existing population?

If an extra cost of $2 billion is imposed on contemporary society by unnecessarily stringent standards for disposal of high level wastes, this resource will not be available (a) to help prevent premature deaths today, perhaps 20,000 (@ $100,000/life saved) or (b) to help continue development of society perhaps to the point of cures for many forms of cancer, as well as to the point of energy substitutes for the currently usable forms.

Hence, spending an extra $2 billion for unduly and unnecessarily stringent high-level radioactive waste disposal may impose greater risks both today and in the future. And it is by no means clear that society values a premature death deferred 10,000 years from now nearly as much as one deferred in the next 100 years.

TABLE A

NUMBER OF POSSIBLE CANCER CASES DUE TO IONIZING RADIATION[1]

ORIGIN	NO. OF CASES PER YR.[2]	NO. OF CASES PER 10,000 YR.[2]
High-level Rad. Waste Disposal[3]	up to 0.1	up to 1,000
Uranium Mill Tailings[4]		
- Unprotected†	3	30,000*
- Protected (covered, etc.)	0.03	300*
Indoor Air Pollution		
- Residential Exposure[5]	1,000 to 20,000	10,000,000 to 200,000,000*
- Residential Weatherization (added cases)[5] (Nero Estimate)	250 to 5,000	2,500,000 to 50,000,000*
- Residential Weatherization (added cases)[6]	10,000 to 20,000	100,000,000 to 200,000,000*
Background Radiation[7]	3,000 to 4,000	30,000,000 to 40,000,000

[Cancer Deaths (U.S.)[8] (all causes) 430,000]

Notes: 1 These numbers are all calculated on the same basis using a linear non-threshold dose response model, as noted on pp. A-7-3 and A-7-4 of this report. The linear non-threshold model involves a high degree of speculation, and the resulting values have little merit as absolute indicators of the numbers of biological effects that may occur. It has been used here to provide a framework within which relative risks from various radiation exposure situations can be compared.

2 Assuming constant U.S. population and culture - numbers with (*) are extrapolated from annual values.

3 EPA proposed rule 40 CFR Part 191 (December 1982) number per 100,000 MTHM high-level radioactive waste repository.

4 NRC (October 1980). "Uranium Mill Licensing Requirements: Final Rules," Federal Register, 45, No. 194, 65521-65538. Radon inhalation exposures.

TABLE A (Continued)

[5] Nero, A.V. "Indoor Radiation Exposures From ^{222}Rn and Its Daughters: A View of the Issue," Health Physics, 45, No.2, (August 1983), 277-288.

[6] EPA Report EPA 520/4-78-013 (revised printing, July 1979)

[7] NAS/NRC, The Effects on Populations of Exposure to Low Level of Ionizing Radiation (November 1972) - (1972 BEIR Report).

[8] American Cancer Society, Cancer Facts and Figures - 1982, 1981.

† Does not include health effects from water pathways.

1.5 Time Scope for Risk Analysis

The EPA proposed rule is intended to apply for 10,000 years following disposal. This period was selected by EPA because it was considered sufficiently long for some radioactive release to reach the accessible environment, yet short enough to permit reasonable predictions of waste behavior.

Some have argued for longer time frames on the scientific grounds that the risks are more important (possibly larger) after 10,000 years than during the first 10,000. This is usually based on the assumption that the future society, instead of testing its water for radioactivity as is required today, will be completely ignorant of its presence. It appears to the subgroup that unless society reverts to a caveman stage, in which case other hazards will be far more significant, it is more reasonable to assume that any society using this water after 10,000 years will be advanced technologically at least as far as we are today, and testing of water and cleanup, if necessary, would take place.

1.6 The Role of Benefits

The proposed standards appear to impose more stringent requirements for light water reactor (LWR) fuel in which 6% of its original uranium has been burned out than for LWR fuel in which only 3% has been fissioned. Yet society would have received twice as much benefit (in the form of electricity) from the higher burnup fuel, per ton of uranium mined. Is this sensible?

Many societal decisions relate the accepted or acceptable risk to the associated benefit. Thus, EPA itself has different risk acceptance levels for various pesticides and toxic substances, allowing greater risk where greater benefit is involved. Similarly, in the practice of medicine, some diagnostic tests involving a probing of arteries near the heart may involve a risk of severe consequences of the order of 1 in 500, but the tests are nevertheless recommended when the potential benefit warrants such a risk. On the other hand, much smaller risks per person must be associated with vaccination for influenza.

2. Probabilistic Methodology

The EPA staff, with the assistance of A.D. Little, have developed a useful methodology for evaluating the consequences of postulated release, as well as a rough way of estimating the frequency (or probability) of such releases. The EPA staff appear to believe that they have made very conservative assumptions in many areas and still calculate that their generic repository can meet the proposed standard, including its probabilistic requirements.

However, several strong disagreements have been expressed with the acceptability of the probabilistic portion of the proposed standards.

a) Koplik, Kaplan and Ross, in their recent paper in Reviews of Modern Physics, question any attempt to quantify probabilities. Ross repeats this objection in his comments on the proposed rule.

b) The NRC staff strongly question the workability of quantitative probabilistic requirements for the defined releases. The NRC states, in part, "Numerical estimates of the probabilities or frequencies of some future events may not be meaningful. The NRC considers that identification and evaluation of such events and processes will require considerable judgment and therefore will not be amenable to quantification by statistical analyses without the inclusion of very broad ranges of uncertainty. These uncertainty ranges will make it difficult, if not impossible, to combine the probabilities of such events with enough precision to make a meaningful contribution to a licensing proceeding."

c) Representatives of Sandia National Laboratory have shown that some scenarios may violate the release limits proposed in the standard. These violations are mainly due to the large uncertainties in the parameters affecting groundwater flow and radionuclide transport, and large uncertainties in estimating the probability of the scenarios of interest. During discussions with the Risk Assessment Subgroup, Sandia's staff indicated that relaxing the release and probability limits will facilitate a finding of reasonable assurance in meeting the standard.

d) There appears to be much disagreement among workers in the field as to whether intrusion is a relatively likely event or a highly unlikely event.

The EPA staff, with the aid of the Sandia National Laboratories, Arthur D. Little Corp., and others, are having a series of additional studies performed to provide insight into whether it is practical to meet the proposed standard.

Based on the information available to the Subgroup on Risk Methodology, the Subgroup has insufficient basis for agreeing with the EPA staff that the proposed release criterion with its probabilistic corollary can be demonstrated to have been met with reasonable assurance, and that this could be argued definitively in a legal setting.

Usually, meeting a probabilistic criterion with a considerable or high confidence means that the real value of risk is significantly less. Hence, it is to be anticipated that when the NRC requires adequate assurance that the EPA standard has been met, the likely health effects will be substantially less than those used as a guideline in the proposed standards.

Findings and Recommendations

A. Numerical Limits--Levels of Protections.

Finding #A-1 For most repository technologies and site types currently under active consideration by DOE, there appears to be a reasonable likelihood that the levels of protection sought by EPA in its draft standard can be met, in fact. However, very large uncertainties exist in our knowledge of the probabilities of many postulated release scenarios, and many input parameters are poorly known; hence, we believe that repository designers will find it quite difficult and possibly excessively expensive to demonstrate with reasonable or high assurance that the levels of protection sought by EPA in the draft standard have been met.

Recommendation #A-1 We recommend that EPA, in developing its standard, be guided by the requirement that the standard should provide adequate protection with regard to societal effects; that it can be met technically for at least some known technological approaches; that it will permit NRC to make a favorable finding with reasonable assurance; and that it does not needlessly induce or lend itself to long controversy and delay in arriving at a decision in the regulatory framework and in court.

Recommendation #A-2

1. The probabilistic release criteria in the draft standard should be modified to read "Analysis of repository performance shall demonstrate that there shall be less than 50% chance of exceeding the Table 2 limits, modified as is appropriate, on curies released to the accessible environment in 10,000 years. Events whose median frequency is less than 10^{-3} in the first 10,000 years need not be considered."

2. The Subgroup also recommends that the release limits in Table 2 be modified by a factor(s) such that, based on the studies available to it up to the time of setting the standard, EPA has high confidence that it will be practical for high-level waste repositories to be built and operated with reasonable assurance that the EPA standard has been met. The EPA position should be subject to the constraints (1) that the facility/waste package/siting costs are not unduly large (i.e., that the disposal process remains practical and cost effective), and (2) that the criteria for disposal of high-level waste remain substantially more stringent as to societal risks than is currently accepted by EPA for hazardous chemical wastes or exists from uranium mill tailings.

3. The Subgroup recommends that, if EPA cannot provide convincing evidence that a quantitative probabilistic condition on its modified Table 2 release limits is practical to meet, regardless of what definition of accessible environment is finally adopted, and if there is not considerable assurance that such a probabilistic condition will not

lead to serious impediments (legal or otherwise) to the licensing of high-level waste geologic repositories, EPA should adopt qualitative criteria, such as those suggested by the NRC.

B. EPA's Method for Expressing the Desired Level of Protection

Finding #B-1 We find that the method chosen by EPA for expressing the level of protection required of a repository, involving a demonstration by the designer that certain radionuclide "release limits" have not been exceeded, is a satisfactory approach to fulfilling EPA's standard-setting mandate. The "release limit" approach has the attractive feature that a repository designer can work toward release-limit design objectives in an engineering sense, modifying his design to achieve these objectives. At the same time, the release limits are close enough to the desired endpoint of environmental protection (limit to human doses) that they bear a reasonable relationship to this end-point; but the designer is not burdened with demonstrating that the specific endpoint, doses, are themselves not exceeded.

Finding #B-2 We find that an approach to the EPA standard employing "individual dose limits" considering "maximally exposed individual," or alternatively some "average exposed individual, would in practice be very difficult to meet with high assurance for very long times for any repository concept currently under active consideration, if one assumes no monitoring for radioactivity or cleanup. This is partly because, for the far distant future, there cannot be much "assurance" that a single individual might not, either foolishly, or ignorantly, or even deliberately, compromise the repository's integrity to the extent of making himself or some few other individuals vulnerable to large radioactive exposures.

Recommendation #B-1, Based on Findings B-1 and B-2 We recommend that EPA retain the "release limit" approach as its basic mechanism within 40CFR191 for assuring adequate environmental protection from deep geologic radioactive waste disposal.

Recommendation #B-2
We recommend that for the first 500 years the EPA standard should embody an extremely low likelihood that increases in radioactivity concentration approaching the limits allowed by the EPA drinking water standards will be found in potable well water drawn from a well adjacent to the site of the repository. In this way, the next 20 to 25 generations would be afforded an extremely low risk. For longer time periods, we recommend that EPA rely on the assumption that standards similar to today's drinking water standards will exist to protect groups of individuals, and that the proposed EPA societal criterion (modified according to our other recommendations) be retained as the basis for affording adequate protection in general.

Background The proposed EPA standard addresses only societal doses, averaged over a suitably large population. In general, it is expected that the risk to any individual will be extremely small for all technologies and site types under active consideration. However, there are exceptions: for certain site types under certain unusual conditions, one can postulate physically feasible scenarios in which a limited number of individuals might use water drawn from an aquifer which has low flow rates and relatively greater concentration of radioactive materials than the typical aquifer; such aquifers located in the "accessible environment" as defined, present a possible route whereby quite large doses could be delivered to individuals. These doses would occur long into the future (thousands of years).

In principle, these scenarios cannot be ruled out for at least some of the site types and technologies now under active consideration; whether the standard should be cast in a form that rules them out is the issue discussed here! There are other considerations: for example, if one assumes that the present EPA drinking water standards will apply in this distant future, then the large doses would be prevented by tests required at that time, except for those few individuals whose water did not require testing under regulations then in force.

The intrusion issue is another that gives difficulty if a standard incorporating individual dose limits were promulgated by EPA: accidental or even purposeful intrusion could contaminate the intruder himself quite heavily, and might contaminate other innocent individuals, especially if one assumes that no radioactivity measurements are made.

It is important to reiterate our conclusion that acceptance of the present EPA-proposed approach does imply possibly high doses for some individuals using water in the "accessible environment," in some rare scenarios for some technologies and site types now under active consideration.

C. Time Frame Considered

Finding #C-1 We find that in constructing and applying analytical models of repository performance, there is a significantly greater difficulty in modeling the period beyond about 10,000 years than in modeling the period up to about 10,000 years. This is because in the earlier period there is greater assurance that certain important geological processes (glaciation, tectonic changes, vulcanism, etc.) will not differ much from the present situation, while beyond about 10,000 years the degree of assurance falls off significantly.

Finding #C-2 We find that for certain long-lived radionuclides likely to be placed in repositories (or daughters of these), the impact on the accessible environment is likely to be greater in the period after about 10,000 years than before. Also, some natural phenomena such as glaciation could become significantly more likely if a time period of 50,000 years rather than 10,000 years is considered. However, we find that the degree of confidence with which impacts can be modeled further in the future is poor. We conclude that assurance of adequate repository performance can be attained best by concentrating analytical effort and repository design effort on achieving satisfactory performance through the first 10,000 years.

Finding #C-3 We find that models are able to give some useful insights concerning differences among sites further in the future than the first 10,000 years, especially when the models are exercised parametrically to explore sensitivity to various parameters or postulated scenarios. These insights would be qualitative or semi-quantitative, even though the results of the models appear on their face to be quantitative.

Recommendation #C-1, Based on Findings C-1, C-2, C-3
We recommend that EPA retain the 10,000-year time period it has selected as the basis for determining the adequacy of repository performance. We believe that the use of formal numerical criteria limited to this approximate time period is an acceptable regulatory approach.

Recommendation #C-2, Based on Findings C-1, C-2, C-3
We recommend that EPA adopt as part of its Federal Radiation Protection Guidance the advice that "the selection of sites for high-level waste disposal systems shall take into consideration potential releases of radioactivity into the accessible environment for times somewhat longer than 10,000 years, say 50,000 years." The guidance should state that the purpose of the analysis is to provide assurance within the large uncertainty band inherent in such analyses that disposal systems are expected to continue to release radioactivity slowly without an abrupt, very large degradation in performance from that required in the first 10,000 years. Such an evaluation would be only one attribute to be included in the overall judgment among sites; however, as stated in recommendation C-1, the licensing of a repository should be based only on meeting the EPA standard for the first 10,000 years.

Background Several contributors to the comment record have indicated that a cut-off at 10,000 years does not necessarily assure adequate protection. Considerations of about 100,000 years, or even 1 million years, are suggested; and the WISP report suggests considering all future times.

It is apparent that some radionuclides, such as progeny of the heavy elements, have impacts beyond 10,000 years that might be important. However, it is also apparent that modeling these impacts becomes increasingly difficult and uncertain in that time period. The subgroup questions that health effects farther in time should be given great weight compared to those during the first 10,000 years.

The solution we offer is that consideration be given to a later time period, in the form of estimates of impacts to 50,000 years, as one input among several that goes into the process of site selection.

There are other issues involved in consideration of time periods so far into the future. For example, the form that society will take defies definition...even 1,000 years from now. It could be that the somatic impacts of concern are mostly curable by then. Methods for cleaning up radioactively contaminated water already exist.

In any event, there is no other aspect of hazard regulation that considers impacts even as far as 10,000 years into the future.

D. Ore Bodies Impacts

Finding #D-1 The EPA-sponsored analysis of the radiological impacts of ore bodies bearing uranium, which was used as a point of comparison with the calculated risks of future repositories, contains conservatisms and large uncertainties. An improved analysis might clarify some of these conservatisms and narrow some of the uncertainties, but large uncertainties would remain simply because the range of natural ore body properties is so large.

Finding #D-2 The comparison between repository future impacts and the impacts of comparable ore bodies has a simplistic appeal. The notion that the long-term impact of repositories would be no greater than that of undisturbed ore has an attraction of undeniable value. However, we find that the comparison is subject to widespread misunderstanding and is not made for any other materials so far as we know.

Recommendation #D-1, Based on Findings #D-1 and #D-2 We recommend that the EPA final standard down-play the ore body comparison.

Background There is a widespread misunderstanding that the EPA chose the level of protection to achieve an impact less than that of the undisturbed ore bodies; this is not true. There is also such a broad variation among ore bodies in nature that no such thing as a "typical" ore body exists, insofar as its impacts are concerned.

Also, we have not uncovered any other materials disposed of in the earth for which this comparison is made: imagine comparing the impact of undisturbed iron ore with the impact of disposing of used automobiles by burial! More complicated is the impact of organic chemicals compared to the impact of the undisturbed petroleum deep underground ...Here the chemical transformations of advanced technologies are more analogous to the fissioning of uranium to produce quite different radioactive materials.

For these reasons, we believe that the ore body analogy should be down-played by EPA.

E. Stringency Of Release Limits

be modeled further in the future is poor. We conclude that assurance of adequate repository performance can be attained best by concentrating analytical effort and repository design effort on achieving satisfactory performance through the first 10,000 years.

Finding #C-3 We find that models are able to give some useful insights concerning differences among sites further in the future than the first 10,000 years, especially when the models are exercised parametrically to explore sensitivity to various parameters or postulated scenarios. These insights would be qualitative or semi-quantitative, even though the results of the models appear on their face to be quantitative.

Recommendation #C-1, Based on Findings C-1, C-2, C-3
We recommend that EPA retain the 10,000-year time period it has selected as the basis for determining the adequacy of repository performance. We believe that the use of formal numerical criteria limited to this approximate time period is an acceptable regulatory approach.

Recommendation #C-2, Based on Findings C-1, C-2, C-3
We recommend that EPA adopt as part of its Federal Radiation Protection Guidance the advice that "the selection of sites for high-level waste disposal systems shall take into consideration potential releases of radioactivity into the accessible environment for times somewhat longer than 10,000 years, say 50,000 years." The guidance should state that the purpose of the analysis is to provide assurance within the large uncertainty band inherent in such analyses that disposal systems are expected to continue to release radioactivity slowly without an abrupt, very large degradation in performance from that required in the first 10,000 years. Such an evaluation would be only one attribute to be included in the overall judgment among sites; however, as stated in recommendation C-1, the licensing of a repository should be based only on meeting the EPA standard for the first 10,000 years.

Background Several contributors to the comment record have indicated that a cut-off at 10,000 years does not necessarily assure adequate protection. Considerations of about 100,000 years, or even 1 million years, are suggested; and the WISP report suggests considering all future times.

It is apparent that some radionuclides, such as progeny of the heavy elements, have impacts beyond 10,000 years that might be important. However, it is also apparent that modeling these impacts becomes increasingly difficult and uncertain in that time period. The subgroup questions that health effects farther in time should be given great weight compared to those during the first 10,000 years.

The solution we offer is that consideration be given to a later time period, in the form of estimates of impacts to 50,000 years, as one input among several that goes into the process of site selection.

There are other issues involved in consideration of time periods so far into the future. For example, the form that society will take defies definition...even 1,000 years from now. It could be that the somatic impacts of concern are mostly curable by then. Methods for cleaning up radioactively contaminated water already exist.

In any event, there is no other aspect of hazard regulation that considers impacts even as far as 10,000 years into the future.

D. Ore Bodies Impacts

Finding #D-1 The EPA-sponsored analysis of the radiological impacts of ore bodies bearing uranium, which was used as a point of comparison with the calculated risks of future repositories, contains conservatisms and large uncertainties. An improved analysis might clarify some of these conservatisms and narrow some of the uncertainties, but large uncertainties would remain simply because the range of natural ore body properties is so large.

Finding #D-2 The comparison between repository future impacts and the impacts of comparable ore bodies has a simplistic appeal. The notion that the long-term impact of repositories would be no greater than that of undisturbed ore has an attraction of undeniable value. However, we find that the comparison is subject to widespread misunderstanding and is not made for any other materials so far as we know.

Recommendation #D-1, Based on Findings #D-1 and #D-2 We recommend that the EPA final standard down-play the ore body comparison.

Background There is a widespread misunderstanding that the EPA chose the level of protection to achieve an impact less than that of the undisturbed ore bodies; this is not true. There is also such a broad variation among ore bodies in nature that no such thing as a "typical" ore body exists, insofar as its impacts are concerned.

Also, we have not uncovered any other materials disposed of in the earth for which this comparison is made: imagine comparing the impact of undisturbed iron ore with the impact of disposing of used automobiles by burial! More complicated is the impact of organic chemicals compared to the impact of the undisturbed petroleum deep underground ...Here the chemical transformations of advanced technologies are more analogous to the fissioning of uranium to produce quite different radioactive materials.

For these reasons, we believe that the ore body analogy should be down-played by EPA.

E. Stringency Of Release Limits

Finding #E-1 We find that, on the basis of comparison with present control practices over other man-made and natural risks to which the general public are exposed, the societal objectives and release limits presently proposed by EPA have been derived with excessive conservatism with respect to radiation protection for high-level radioactive waste disposal repositories.

Recommendation #E-1 The Subgroup recommends that the proposed societal risk objective (limit of 1,000 estimated premature cancer deaths in 10,000 years) be relaxed by at least a factor of 10, and that the proposed release standards should be relaxed accordingly.

F. References

1. Cohen, B. L., Long-Term Consequences of the Linear No-Threshold Dose-Response Relationship for Chemical Carginogens, Journal of Risk Analysis, Vol. 1, No. 4, December 1981.

2. Hirschhorn, J. S. and Gough, M., Controlling Toxic Waste Means More Than Disposal, Conference on Institutional Stability and the Disposal of Nuclear and Chemically Toxic Wastes, Massachusetts Institute of Technology, May 1983.

3. Hurwitz, H., Residential Radiological Standards, Letter to Science Magazine, March 25, 1983.

4. Kasperson, R. E., Equality Issues in Radioactive Waste Management: The Legal Problem, ibid.

5. Koplik, C. M., Kaplan, M. F., and Ross, B., The Safety of Repositories for Highly Radioactive Wastes, Review of Modern Physics, Vol. 54, No. 1, January 1982.

6. Nero, A. V., Indoor Radiation Exposure from ^{222}Rn and its Daughters: A View of the Issue, Health Physics, 45, No. 2, August 1983.

APPENDIX A-2

REPORT

of the

ENVIRONMENTAL PATHWAYS SUBGROUP

January 17, 1984

Dr. Stephen V. Kaye, Chairman
Dr. Bruce B. Boecker
Dr. Terry R. Lash
Dr. Frank L. Parker

Recommendation 1

The EPA should consider using the concept of effective dose equivalent in setting a dose limit in Subpart A of 40 CFR 191.

Background for Recommendation 1

In Subpart A of 40 CFR 191, the EPA specifies dose limits of 25 mrem/yr to whole body, 75 mrem/yr to the thyroid, or 25 mrem/yr to any other organ. These limits are the same as those in 40 CFR 190, and they are based essentially on the critical organ approach to radiation protection. In Subpart B, however, the radionuclide release limits are derived using a sum of dose equivalents to different body organs weighted by the stochastic risk factors for each organ. This is the same approach as the effective dose equivalent by the International Commission on Radiation Protection in their reports (ICRP 26 and 30). Thus, the two approaches to calculating doses in Subpart A and B are clearly not consistent.

There are two basic problems with the dose limitation approach used in Subpart A: (1) the ICRP no longer calculates a whole body dose as the total energy absorbed in all body tissues divided by the 70 kg mass of the body; (2) the various dose limits to different tissues do not yield the same number of health effects. With regard to the first, the ICRP now recognizes that it is specific body tissues and not "whole body" which are at risk. With regard to the second, the problem of different risks leads to predicted health effects which differ by a factor of 25 between whole body and thyroid and more than a factor of 10 between different organs at risk, excluding whole body. Thus, the dose limits are not clearly related to risk.

Recommendation 2

The EPA should consider ways to ensure that the models and associated input parameters used for the environmental pathway and health risk calculations are clearly defined, reproducible, and based upon the best information currently available.

Background for Recommendation 2

The computations of environmental dose commitment used in support of the proposed standards were made several years ago with dosimetric approaches and computer models available at that time. Some improvements in these areas have been made in the intervening years. Incorporation of these improvements, where applicable, would increase the technical basis for the proposed standards. Several changes that fall into this category are changes in the quality factor for alpha particles from 10 to 20, elimination of the use of a factor for nonuniformity of dose in bone, and consideration of different values for GI absorption based on the ingestion of radionuclides incorporated into foodstuffs. One way to accomplish an updating of methodology would be to use the RADRISK computer code that reflects the latest ICRP views on internal dosimetry models. Regardless of what models are used, the results are much more convincing if they can be reproduced by others. This requires that all applicable input parameters that are used be clearly tabulated to ensure the same factors are used by all interested parties. In the material currently available, a number of these parameters are embedded in computer programs and are difficult to verify.

Having made the calculations with the best available information, it is important to use the results of the calculations consistently when deriving release limits such as those listed in Table 2 of 40 CFR 191. The value listed for ^{99}Tc calculated in a manner similar to other radionuclides is approximately 35,000 instead of the 10,000 listed. This reduction appears to have been made arbitrarily. Likewise, the basis for the value for "any other alpha-emitting radionuclide" and "any other radionuclide which does not emit alpha particles" is not clear and should be carefully described since these values apply to a large number of individual radionuclides.

The conversion of environmental dose commitments to expected health effects involves the use of a risk value for each organ considered. Several different compilations of health risk estimates of this type have been made during the last decade. The strongest approach that could be made in these analyses would be to use a consistent set as proposed by the ICRP, UNSCEAR, or BEIR III. If for some reason this is not feasible, exceptions to values from a generally recognized report should be documented and explained. The origin of the values currently being used is not specified.

<u>Recommendation 3</u>

The EPA should consider using up-to-date dosimetry data to calculate organ doses for external exposure to ^{93}Zr and ^{126}Sn on a contaminated ground surface.

<u>Background for Recommendation 3</u>

Out-of-date dosimetry factors from the 1967 report, ORNL-4101, are considered inappropriate for the EPA's calculations of organ doses for external exposure to ^{93}Zr and ^{126}Sn on a contaminated ground surface. The main difficulty with the data in ORNL-4101 is that only the dose rate in air above ground surface is given, not the dose to any body organs. For ^{93}Zr in particular, which produces only X rays of energy less than 20 keV from decay of the ^{93m}Nb daughter, the data in <u>Health Physics</u> (Vol. 38, p. 543, 1980) show that the use of the dose in air by the EPA overestimates the dose to any body organs by at least 2-3 orders of magnitude. Thus, the EPA has greatly overestimated the health risk from external exposure to ^{93}Zr in surface soil. For ^{126}Sn, on the other hand, the external dose rate in air obtained from ORNL-4101 is not significantly different from the dose rate factors for different body organs found in the Health Physics paper, but the calculations should still be based on up-to-date dosimetry data for ^{126}Sn and the daughter products ^{126m}Sb and ^{126}Sb.

Recommendation 4

The EPA should consider a re-evaluation of the assumed fraction of activity in rivers which is transported to the land surface via irrigation.

Background for Recommendation 4

The average flow in streams in the contiguous United States is 1,200 billion gallons per day (BGD) [The Nation's Water Resources: 1975-2000, Vol. 1, Summary, U. S. Water Resources Council (WRC), Dec. 1978, p 15]. Fresh water withdrawals from streams and ground water for irrigation in 1975 were 160 BGD (WRC, p. 37) so that on the average in the contiguous United States only a maximum of 13% of stream flow was used for irrigation. For example, California has a total stream flow of 47 BGD and is the single largest user of irrigation water, 35 BGD. The total ground water use is 19 BGD. Therefore, if all the ground water (19 billion gallons) were used for irrigation, then irrigation would require 34% (35-19/47) of stream flow or if all irrigation water were stream flow then it would require 74% (35/47) of stream flow.

The percentage of cropland irrigated can also be deduced from the WRC report. There are 45 million acres of irrigated cropland out of a total of 422 million acres in crops. The total land surface in the contiguous United States is 3,022,261 square miles, or almost 2 billion acres (Statistical Abstracts of the United States - 1974, U. S. Bureau of the Census, p. 5.). Therefore, the approximate total percentage of land surface in crops is 22%, and in irrigated crops is 2%.

Recommendation 5

The EPA should consider the recycling of activity removed from soils to rivers, particularly if the fraction of activity in rivers which is removed by irrigation is assumed to be relatively large.

Background for Recommendation 5

In the EPA models, activity removed from the soil root zone, as determined by the soil leaching coefficient, is assumed to be no longer available for human exposures. This assumption could lead to an underestimate of the total residence time of activity in soils for radionuclides with relatively large soil leaching coefficients, e.g., for ^{99}Tc. It is easy to estimate the effects of this recycling of activity on the total residence time of radionuclides in the soil compartment. For example, about 85% of the water in soils which is not removed by evaporation or evapotranspiration is returned directly to rivers; the remaining 15% goes to groundwater which EPA apparently treats as an inaccessible compartment. Then, for rapid removal and recycling of radionuclides in soils and rivers, it is easy to show that the fraction of the activity released to a river which is eventually deposited on the surface is given by

$$f = f_R[1/(1 - 0.85f_R)],$$

where f_R is the fraction of the river flow which is assumed to be transported to the land surface via irrigation. If $f_R = 0.5$ as in the EPA analysis, recycling would increase all exposures from activity in soil by a factor that could be as large as 2, depending on the value chosen for the soil leaching coefficient. If $f_R = 0.1$ were chosen instead, then the increase due to recycling would only be about 10% or less.

Recommendation 6

The EPA should consider re-evaluation of the terrestrial food-chain pathways for isotopes of Cs, Ra, U, Pu, and Am in light of the comparison with a natural analog model.

Background for Recommendation 6

The comparison with a natural analog model for transfer of elements from soil to man suggests that the EPA terrestrial food-chain pathways models may overestimate exposures for long-lived isotopes of Cs, Ra, U, Pu, and Am by about a factor of 5. The EPA should consider whether such an adjustment for these pathways and elements would be desirable. A re-evaluation of the terrestrial food-chain pathways could involve, for example, a comparison of the EPA data base with recent data published by Yook Ng and coworkers at Lawrence Livermore National Laboratory, in order to determine if key parameters may have been overestimated.

The natural analog model on which this recommendation is based assumes that an upper limit for the probability of movement of radionuclides from soil to man via terrestrial food chains can be estimated from the known concentration of stableelement analogs in soil and the known total intake rate of the analogs by man. This approach is most appropriate for long-lived radionuclides which should achieve equilibrium with their natural analogs before radioactive decay occurs. It provides a simple, one-parameter description of the transfer of elements from soil to man, which can be used to evaluate the multi-parameter EPA food-chain model. Average soil concentrations of elements can be obtained, for example, from the compilation of Vinogradov [The Geochemistry of Rare and Dispersed Chemical Elements in Soils, Consultants Bureau, Inc., New York (1959)], and the average intake rates by man are available in ICRP Publication 23.

ommendation 7

The EPA should consider re-evaluation of the environmental trans- c of ^{129}I using information on the known cycling of stable iodine in environment.

kground for Recommendation 7

Calculation of long-term dose from ^{129}I should be based on the wn cycling of stable iodine in the environment. This would probab- give somewhat higher exposures per unit release for the soil-to-man hways than those given by the EPA models. Specifically, the soil ching coefficient for iodine given in Table 5-4 of the EPA Environ- tal Pathways report by Smith (EPA (520/5-80-002) is known to be ut two orders of magnitude too high, i.e., the mean residence time iodine in soil assumed by the EPA is about two orders of magnitude low and, thus, leads to an underprediction of exposures via the l to man pathways [see Environ. Int. 5, 15, (1981)].

ommendation 8

The EPA should consider use of appropriate models for the time- endence of resuspended activity in soil and external exposure from taminated soil.

kground for Recommendation 8

The EPA should consider modification of the resuspension model to e into account that resuspension occurs only from the top soil layer, from the entire root zone. The appropriate time dependence of re- pension depends on whether the soil is assumed to be undisturbed or quently plowed. A model for undisturbed soil has been given by nett [p. 367 in Transuranic Nuclides in the Environment, IAEA 76)]. In either case, a more suitable model would probably reduce dicted exposures to resuspended plutonium by about a factor of 5. s, the EPA model is probably quite conservative. Calculations of ernal exposures from contaminated soil should either be based on a lished model for undisturbed soil [Appendix VI of the Reactor Safety dy, WASH-1400 (1975)] or take into account the shielding provided soil if uniform mixing in the 15 cm root zone is assumed [D. C. her and A. L. Sjoreen, Dose-Rate Conversion Factors for External osure to Photon Emitters in Soil, submitted to Health Physics]. her of these models would provide external doses which are signif- ntly less than those estimated by the EPA, i.e., the EPA calcula- ns are probably conservative.

ommendation 9

The EPA should consider addressing more fully the levels of uncer- nty in the environmental pathways analyses.

Background for Recommendation 9

The analyses of environmental pathways explicitly recognize that there are substantial uncertainties in the estimates of doses delivered to populations from specified curie releases of radionuclides from repositories. Nowhere, however, does EPA try to assess the overall level of uncertainty in its calculations, nor does EPA attempt to compare the level of uncertainty in the pathways analyses to uncertainties in the analyses of radionuclide movement through the geosphere to the accessible environment or in the conversions of doses to cancer and genetic mutations in humans. An overall assessment of uncertainty in the effects of specified curie releases might be useful for evaluating the suitability of the proposed assurance requirements and in determining the appropriateness of the values chosen for release limits to the accessible environment.

The uncertainties in parametric values in the environmental pathways analysis could be placed into four categories, as follows:

1. Use of average values instead of situation-specific ones (e.g., proportion of river water used for irrigation);

2. Variations in results from different studies and experiments (e.g., surface resuspension of radionuclides);

3. Lack of knowledge about the behavior of radionuclides in the environment over very long periods of time (e.g., the resident time of radionuclides in the "available environment"); and

4. Lack of knowledge about human behavior and systems in the far future (e.g., farming techniques and diets may be substantially different).

The EPA analysis usually does not evaluate the type and extent of uncertainty associated with its choices of parameters. Moreover, EPA does not appear to have used a consistent philosophy of dealing with uncertainty. In some cases, assumptions are knowingly made that are believed to lead to high estimates of population dose. For instance, the drinking water pathway analysis conservatively assumed that neither sedimentation in the hypothetically contaminated river nor filtration in the water supply would remove radionuclides discharged into the river. Depending on the specific characteristics of the river and water supply system, the EPA approach overestimates the population dose from this pathway by a factor of ten or more.

On the other hand, some parametric choices are "best guesses" that may be either too high or too low. For instance, the value used for absorption of neptunium-237 through the human gut is EPA's best estimate based on current knowledge, although the uncertainty may be an order of magnitude.

Recommendation 10

The EPA should consider presenting a discussion that would put in perspective the level of risk of 1,000 health effects in 10,000 years.

Background for Recommendation 10

The baseline EPA health standard is 1,000 excess deaths in 10,000 years. This then is 0.1 death per year from a 70,000 MT repository. Assuming that we will have five repositories, this is equivalent to increasing the annual death rate in the U.S. of 2,000,000 from all causes, or 430,000 deaths from cancer, by less than 0.5 deaths.

Further assume that radiation dose from cosmic rays is increased 1 millirem per year for each additional 100 feet in elevation. The EPA standard would be reached if each of us were 1 foot closer to the sky, assuming that the risk to the population from genetic and somatic effects of radiation is 200 excess deaths per million persons exposed to one rad and that the U. S. population is 230 million. It is also equivalent to each of us spending one-half minute in Denver. With 50,000 deaths from automobile accidents each year, the EPA standards are equivalent to the automobile deaths that occur in a five-minute period. On jet passenger planes the dose is approximately one millirem per 1,000 miles; therefore, flying 100,000 miles is equivalent to the annual deaths from one repository or each of us flying 1/400 of a second. One could make an infinite number of comparisons with the EPA standards and see that they are not only impossible to detect, they are also so low that they must truly be considered *de minimis*.

APPENDIX A-3

REPORT

of the

SUBPART A REQUIREMENTS SUBGROUP

January 17, 1984

Dr. Konrad Krauskopf, Chairman
Mr. Robert Catlin
Dr. Charles Fairhurst
Dr. Stephen Kaye
Dr. Terry Lash

Recommendation 1

The EPA should consider changing the definition of high-level radioactive waste to the following:

"High-level radioactive waste" means (1) spent nuclear fuel if disposed of without reprocessing; (2) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; sufficient concentrations, as a general guideline, mean concentrations greater than those identified in Table 1, but some flexibility is permissible in using these limits for particular kinds of waste and particular disposal systems; (3) other highly radioactive material that the NRC, consistent with existing law, determines by rule requires permanent isolation. High-level waste may not be converted to low-level waste by dilution, except for very small amounts such as those produced in research or in medical practice.

Background for Recommendation 1

The subgroup prefers this definition because (1) it is consistent with the definition in NWPA, (2) it does not mandate deep geologic disposal of low-level solids that may be derived from high-level liquid waste, (3) it provides a definition of "sufficient concentrations" that is specific and consistent with NRC's definition of low-level waste (10CFR61), yet is somewhat flexible, and (4) it prohibits modifying high-level waste by dilution, except for very small quantities.

The working group has two additional recommendations related to this definition: (1) that concentrations be given as curies per unit volume (rather than unit mass) to correspond to NRC usage in 10CFR61, and (2) that a note be added to Table 1: These limits are intended as guidelines only, and may be somewhat modified if, in the judgment of NRC, this is warranted for particular situations.

The Subcommittee notes that EPA's proposed definition may preclude alternative satisfactory disposal techniques (such as greater confinement disposal) for "intermediate" wastes and wastes needing shorter isolation times.

Recommendation 2

The EPA should check the definition of TRU waste to ensure consistency, both within EPA publications and between EPA publications and those of DOE and NRC.

Background for Recommendation 2

The working group notes that the definition in paragraph 191.02(c) specifies alpha-emitting transuranic isotopes with half-lives greater than one year, while the definition in the Supplementary Information (page 58197, middle column) includes only isotopes with half-lives greater than 20 years. The working group notes also that another possible definition of TRU wastes could be based on the calculated amount of alpha-emitting transuranic isotopes that would be contained in TRU waste after a specified period, say 100 years. For TRU wastes containing appreciable amounts of fission products, still another definition could be based on heat output averaged over a single waste package. Further, the working group notes that other isotopes besides transuranic isotopes, notably Ra-226, are significant alpha emitters and might well be included in the definition.

The working group takes no stand on these possible variations in the definition of TRU wastes, but urges EPA to make sure that its definition and those of other agencies are consistent.

Recommendation 3

In setting a dose limit (paragraph 191.03(a)), the EPA should consider using the concept of dose equivalent.

Background for Recommendation 3

(1) As noted by the Subgroup on Environmental Pathways, the concept of effective dose equivalent is a more accurate and more up-to-date basis for setting dose limits than the critical-organ approach used by EPA. The subgroup recognizes, however, that using this concept would destroy the parallelism between dose limits proposed in 40CFR190 and those in Subpart A of 40CFR191. Ideally the limits in both 190 and 191 should be based on effective dose equivalent, and the subgroup thinks this change should be made eventually. As to whether the change is desirable in the immediate future, the opinion of the subgroup is divided.

The EPA should present an analysis to show the range of the differences in dose limits calculated by the critical-organ and dose-equivalent approaches, noting that the calculation in 40CFR 190 is several years old and was based on an approach which is no longer in general use and, in fact, was not used in Subpart B.

Recommendation 4

The EPA should analyze the practicality of implementing the suggested dose limits at facilities that include operations of both the uranium fuel cycle and the management and storage of high-level wastes.

Background for Recommendation 4

The suggested dose limits are well below limits based on Federal Radiation Council Guidance. While EPA has demonstrated that the suggested limits, or even lower limits, should be attainable in normal management and storage operations, it is not clear that they are realistic at combined facilities which include operations pertaining to the uranium fuel cycle. For such facilities, some deviation from the suggested limits could be allowed without endangering public health and safety. If analysis shows that some flexibility in the limits is necessary for normal operations at such combined facilities, the subgroup suggests that minor deviations should be permitted without the necessity of requesting variances for unusual operations as described in Section 191.04.

Recommendation 5

EPA should revise paragraph 191.02(e) as follows:

"Management and storage" means any activity, operation, or process, except for transportation, conducted to prepare spent nuclear fuel, high-level radioactive wastes, or transuranic wastes for disposal, the interim storage of any of these materials after their preparation for disposal has been initiated, or activities associated with the disposal of these materials.

This suggested rewording will clarify the distinction between the categories of radioactive waste to be included under 40CFR190 and 40CFR191, and will establish a time for bringing defense waste under the licensing authority of NRC.

Question 1

The proposed 40CFR191 gives no consideration to possible accidental releases of radioactive materials to the environment during management and storage operations. Would the doses that result from such releases be included in normal operations requirements? What action would be expected of the operator and the implementing agency in evaluating compliance with the proposed standard?

The subgroup has no recommendation to make at this point, but it is concerned about accidental releases and wonders if they should be given some attention in the proposed regulation.

APPENDIX A-4

REPORT

of the

ASSURANCE REQUIREMENTS SUBGROUP

November 30, 1983

Dr. Terry Lash, Chairman
Dr. Robert Budnitz
Dr. Konrad Krauskopf
Dr. David Okrent

INTRODUCTION

Section 191.14 of the proposed rule ("Assurance Requirements") specifies seven requirements for the disposal of high-level and transuranic (TRU) wastes. These seven Assurance Requirements supplement the quantitative "Containment Requirements" in Section 191.13. The EPA sees these qualitative requirements as necessary in order to assure compliance with the numerical release limits in Section 191.13, which apply for the first 10,000 years following closure of a repository. In reviewing the proposed Assurance Requirements we have judged them by EPA's criterion of essentiality.

The Subgroup notes that the Assurance Requirements could serve the additional functions of helping to provide protection of the environment beyond 10,000 years, and helping to provide protection for the maximally-exposed individual. We have regarded these two additional objectives as important considerations in judging whether the proposed Assurance Requirements help to provide confidence in the safety of waste disposal systems commensurate with their likely economic and regulatory costs.

The Assurance Requirements are qualitative; they do not themselves specify numerical limits or objectives. The applicant (DOE), however, may find that calculations are necessary or are the most useful approach to show compliance with some of the Assurance Requirements.

In any event, the Subgroup encourages a quantitative approach whenever it may help in the evaluation of a proposed waste disposal system.

To evaluate the proposed Assurance Requirements we have relied principally on (1) the Supplementary Information in the public notice of the proposed standard (47 Federal Register 5820058201, December 29, 1982), (2) the Draft Environmental Impact Statement for 40CFR191: Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste, EPA 520/1-82-025, December 1982 (esp. pp. 120127), and (3) the Draft Regulatory Impact Analysis for 40CFR 191: Environnmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes, EPA 520/1-82-025, December 1982 (esp. pp 61-65). The Subgroup also has benefited from informal briefings by cognizant EPA staff.

The Subgroup reached general agreement on seven of the nine recommendations that follow this Introduction, although not all members subscribe to details of the wording. For Recommendations Seven and Nine we have described alternative wording in order to indicate explicitly the range of views within the Subgroup. A Summary of the Subgroup's recommendations begins on page A-4-20.

On one other aspect of the Assurance Requirements opinions also were sharply divided: the question as to whether Assurance Requirements should be a part of EPA's standard or left for NRC to promulgate. All members of the Subgroup recognized that such requirements are essential somewhere in the regulatory structure, but some (Drs. Budnitz, Krauskopf and Okrent) thought they would be better incorporated in an NRC rule.

If EPA wishes to retain the qualitative assurance requirements, the majority of the Subgroup recommends that they be made part of the Federal Radiation Protection Guidance, rather than part of the standard, if such a step would not lead to protracted legal or interagency disagreements. If such delays are unavoidable, then the majority of the subgroup believes EPA should do no more than place the assurance requirements in the Preamble to 40CFR191.

Recommendation 1

The EPA should consider stating that the Assurance Requirements pertain only to mined, geologic repositories.

Background for Recommendation 1

EPA's technical background studies and draft environmental impact statement assess only mined geologic repositories in detail. Alternatives, such as rock melting, deep hole, deep ocean sediments and space disposal, are not considered quantitatively, in part because the safety of these technologies has not been demonstrated adequately. More research would be necessary before any of these alternatives could be selected for disposal of highly radioactive wastes.

The Department of Energy, moreover, has formally selected deep mined geologic repositories as the technology to be used for permanent isolation of high-level radioactive wastes. The Congress has confirmed this approach, at least for the first two repositories, in the Nuclear Waste Policy Act of 1982.

Some of the proposed Assurance Requirements, however, seem to imply a purpose to eliminate alternatives to mined geologic repositories. Any conclusions tending generically to eliminate alternatives, whether explicitly stated or implied, should be guarded against. Such conclusions are unsupported by up-to-date quantitative analysis and, in any event, they seem premature and unnecessary. DOE is supporting research and development on alternatives to deep mined geologic repositories, even though there is no immediate prospect that their use will be recommended. EPA's proposed Assurance Requirements could have the unfortunate effect of supporting elimination of such R&D. Instead of taking a position on them now, EPA should keep in touch with DOE's R&D efforts and determine at a later time whether standards applicable to alternative technologies should be adopted.

Under this recommendation, Assurance Requirement (g) would no longer be interpreted to foreclose alternative technologies, such as rock melting or deep hole emplacement. Indeed, if EPA continues to hold the position that wastes in any mined geologic repository could be "removed," then this requirement could simply be deleted. The Subgroup finds Assurance Requirement (g) unnecessary and not likely to provide significant additional protection.

Recommendation 2

The EPA should consider eliminating proposed Assurance Requirement (a), which specifies "prompt" disposal of high-level and TRU waste.

Background for Recommendation 2

The principal purpose of this proposed requirement for "prompt" disposal is to foreclose the possiblity of indefinite storage as an alternative to geologic disposal. There is a broad technical consensus that perpetual near-surface storage of long-lived radioactive wastes is inadvisable and potentially dangerous. The EPA, however, apparently has not conducted studies to determine whether "monitored retrievable storage" is an environmentally unacceptable option for relatively long periods of time (e. g., 100 years), or what would constitute prompt disposal. Without analytical studies and more information this proposed requirement is not adequately defined and supported.

Additionally, the Subgroup observes that the Nuclear Waste Policy Act addresses this issue in two ways. First, the Act sets forth a specific schedule for establishment of repositories in the near future. Second, the Act requires DOE to assess in detail the viability of the long-term storage option. The Congress, therefore, seems to have preempted the Agency on this matter. The Subgroup, therefore, finds Assurance Requirement (a) unnecessary and unlikely to provide significant additional protection at this time.

Recommendation 3

The EPA should consider requiring DOE only to analyze and consider as an unfavorable characteristic the potential near-and far-term radiological consequences of natural resources at or near a proposed site, rather than mandating that the mere presence of natural resources automatically precludes development of a site. Analysis may show that the overall safety of the repository would not be jeopardized by the presence of the resources.

We suggest EPA consider the following substitute language for Assurance Requirement (f):

"Places where there has been mining for resources, or where there is reasonable expectation of exploration for scarce or easily accessible resources in the future, or where there is a significant concentration of any material which is not widely available from other sources shall be deemed unfavorable for location of disposal systems. Such places shall be disqualified as sites for disposal systems unless analysis can demonstrate that favorable characteristics more than compensate for the effects of these unfavorable conditions."

Background for Recommendation 3

The presence of significant natural resources at or near a repository site is a highly unfavorable characteristic because it would increase the likelihood of inadvertent human intrusion into the vicinity of a repository. Such intrusion could release radioactivity directly, or it could circumvent enough barriers that natural processes would later release radioactivity to the general environment. This possibility should be fully assessed at each potential site. Additionally, there should be consideration of the possible economic loss if the resources were not recovered because of fear that the integrity of the repository might be jeopardized.

Sites should not be dropped, however, simply because natural resouces are present, provided that other characteristics of the site are favorable. It may be possible by suitable engineering techniques to recover the resources without disturbing a nearby repository or to mitigate the effects of potential human intrusion. The site and engineered barriers should be seen as a system, and a single weakness in a system should not automatically foreclose use of it, if the remaining characteristics are highly favorable and can compensate for the weakness.

Abundant potable groundwater could be a particularly attractive resource in dry areas of the West. Two members of the Subgroup (Drs. Krauskopf and Lash) therefore believe that "potable groundwater" should be identified explicitly as a resource to be considered in comparing the advantages and disadvantage of potential respository sites.

The Subgroup finds that a strong assurance requirement on natural resources adds significantly to confidence in the long-term integrity of waste disposal systems. A slightly modified Assurance Requirement (f) should be retained.

Recommendation 4

The EPA should consider limiting reliance upon active institutional controls to a period of no more than 100 years, and requiring monitoring during this period after closure of a repository. For this purpose Assurance Requirement (d) could be rephrased as follows:

> "In the analysis of disposal systems, designers may not take credit for active institutional controls to isolate the wastes for more than 100 years; and during the period of active controls disposal sites shall be monitored."

Also, the definition of "active institutional controls" should be changed so that guarding and maintaining the repository, as well as controlling releases are all required rather than serving as alternative actions. The definition might be rephrased as follows:

> "'Active institutional controls' means: (1) Guarding a disposal site, and (2) performing maintenance operations and remedial actions at a disposal site, and (3) controlling and cleaning up releases from a disposal site."

Background for Recommendation 4

No releases of radioactivity are expected in the first century following closure of a repository. If that expectation is borne out, there will probably be little societal interest in continuing active controls. Regulations for periods longer than 100 years seem meaningless, because people at the end of that period probably will have little concern with enforcing ancient rules. They should have the option of deciding for themselves whether further active control is needed.

Two members of the Subgroup (Drs. Budnitz and Okrent) believe that there is little basis for selecting 100 years instead of 300 years as the appropriate time period of control. They would therefore find leaving the period of control at "a few hundred years," as proposed by EPA, acceptable. The Subgroup as a whole agrees that monitoring should not be required beyond 100 years in any event.

During the initial 100-year period, or at least near its beginning, much attention will be focused on uncertainties in predictions about future performance of the disposal system. A monitoring or surveillance system designed to test predictions of zero release of radioactivity during the time of active institutional controls would help to reassure the public, and in the unlikely event of appreciable adverse developments would permit remedial measures to be undertaken promptly.

We are not recommending specific monitoring systems, because we wish to allow great latitude in determining what measurements would be useful. The Subgroup is concerned, though, that great care must be taken in designing and implementing any monitoring system that could inadvertently circumvent barriers to the release of radioactivity. Penetrations into the repository area in particular should be cautiously approached, if they are deemed appropriate at all.

The Subgroup believes that a relatively simple monitoring or surveillance effort after closure of a repository would be worth the small economic cost of such a program. The added public confidence gained from the monitoring program should help improve the public acceptability of otherwise safe disposal system.

Recommendation 5

EPA should consider retaining proposed Assurance Requirement (e), but in the document supporting the standard EPA should provide the implementing agencies with more information about the nature of "the most permanent markers and records practicable."

EPA also should consider modifying the definition of such controls as follows:

> "'Passive institutional controls' means: (1) Permanent markers placed at a disposal site, (2) public records and archives, (3) Federal Government ownership and control of land use and (4) other methods of preserving knowledge about the location, design and contents of a disposal system."

Background for Recommendation 5

Passive institutional controls conceivably could provide effective warnings of the potential dangers posed by the wastes far into the future. The Subgroup strongly agrees that such controls should be put in place.

There should be reasonable limits, however, on the level of expenditures for passive controls, and there should be a general assessment of the value of different categories of controls. At one extreme DOE might propose using substantial quantities of highly corrosion-resistant and strong metal alloys, or very massive quantities of more ordinary concrete and steel. Expenditures of large sums of money that such construction projects would entail may not be justified. On the other hand, relatively small markers of degradable materials seem inadequate. More analysis and guidance from EPA is desirable. The environmental impact statement and the regulatory impact analysis would be appropriate documents for this analysis.

Recommendation 6

The EPA should consider relaxing the requirement for engineered barriers in a disposal system for TRU waste that does not contain substantial quantities of radionuclides that will decay to insignificant levels within several hundred years.

Background for Recommendation 6

Some (e.g., contact-handled) TRU wastes do not generate significant heat and may not contain significant amounts of relatively short-lived radionuclides. The potential hazard posed by such wastes does not decrease over the first 1,000 years or longer following disposal. The public safety for a disposal system containing such wastes is provided by the geologic barriers alone, because long-term (i.e. greater than 1,000 years) reliance cannot be placed on engineered barriers as presently conceived in the U.S. disposal system. In other words, the engineered barriers probably would not significantly improve the public safety of a disposal system containing only contact-handled TRU wastes.

The situation is less clear in the case of at least some remote-handled TRU wastes. EPA may want to assess whether engineered barriers are always necessary to ensure protection from the short-lived radionuclides that may be present in this kind of TRU waste.

Recommendation 7

The EPA should consider requiring DOE in its selection of disposal sites to consider possible releases of radioactivity beyond the initial 10,000 year period. The Subgroup, however, could not agree on specific wording for this new Assurance Requirement. Two alternatives (the first favored by Drs. Krauskopf and Lash and the second by Drs. Budnitz and Okrent) are offered below for EPA's consideration:

> (1) "Selection of sites for disposal systems shall take into account potential releases of radioactivity beyond 10,000 years. Particular attention should be focused on potential releases of long-lived alpha-emitting radionuclides and their decay products."
>
> (2) "Selection of sites for disposal systems shall take into consideration potential releases of radioactivity into the accessible environment for times somewhat longer than 10,000 years, say 50,000 years. The purpose of this analysis is to provide assurance within the large uncertainty band inherent in

> such analyses, that disposal systems do not display large degradation in performance from that required in the first 10,000 years. Such an evaluation would not be part of a quantitative requirement but should be in the overall selection among sites."

Background for Recommendation 7

In the Subgroup's view, one purpose of the Assurance Requirements ought to be to provide confidence that the environment is protected beyond 10,000 years. But, in the current draft of the proposed rule, this purpose is not stated in the form of a requirement. The Subgroup suggests that the objective should be explicit.

The Subgroup considered whether quantitative release limits should apply beyond the initial 10,000 year period. There was clear agreement that current analytic methods are too inaccurate to make reliable quantitative predictions of levels of radionuclide releases and their effects on human health for much more than 10,000 years. The Subgroup, therefore, does not recommend that EPA consider modifying the proposed Assurance Requirement to require DOE to show that release beyond 10,000 years meets a numerical standard similar to the Containment Requirements. Rather, the purpose of the proposed analysis is to assure that repository sites are selected so that disposal systems at worst slowly release radioactivity without large decreases in system performance beyond 10,000 years following closure of a repository. Two members of the Subgroup (Drs. Krauskopf and Okrent) believe that the 10,000 year requirement in the proposed EPA standard is already far longer than is required in the regulation of any other hazardous waste and that it is a sufficiently long period from a public health or socio-political point of view. We, therefore, favor no additional formal requirements in the standard beyond the 10,000 year period, recognizing that considerable protection for longer periods would nevertheless be provided automatically by the proposed standards.

Recommendation 8

EPA should consider modifying proposed Assurance Requirement (c) and the background text so that there is greater emphasis on the whole disposal system in comparison to individual barriers. For this purpose Assurance Requirement (c) could be rephrased as follows:

> "Disposal systems for high-level wastes shall use several different types of barriers to isolate the wastes from the accessible environment. Both engineered and natural barriers shall be included. The barriers shall be designed so that they complement each other and help to compensate for unexpected failures."

Additionally, the Supplementary Information preceding the proposed standard should be modified to exclude descriptions of the purpose of this Assurance Requirement as "taking full advantage of the protection each [of the barriers] has to offer." Rather, the objective of multiple barriers should be discussed as providing compensation for unpredicted failures.

Background for Recommendation 8

The Subgroup believes that the multi-barrier approach helps compensate for predictive uncertainties and adds significant certainty that radionuclides in the waste would never seriously threaten public health. The emphasis, however should not be on the ability of every barrier to provide maximum protection by itself alone. Indeed, emphasis on maximizing the effectiveness of individual barriers might result in suboptimization of the overall system.

The Subgroup believes that an Assurance Requirement for multiple barriers is essential. The Supplementary Information preceding the final standard should make clear, however, that each barrier does not, indeed in some cases should not be individually optimized.

Recommendation 9

The Subgroup could not agree on a single recommendation concerning Assurance Requirement (b), which calls for releases to be "as small as reasonably achievable." Three members (Drs. Budnitz, Krauskopf and Okrent) believe that the proposed standard is already so low that trying to reduce possible releases even further is certainly unnecessary and in any event probably unworkable. The other member (Dr. Lash) does not concur and he would rather retain the requirement as proposed by EPA.

Background for Recommendation 9

There should be no man-caused radiation exposures unless there is a compensating benefit. This principle is widely endorsed, and it is meaningfully implemented in situations other than high-level waste disposal. The Subgroup uniformly supports this objective of radiation protection in these other situations. Its use in the case of high-level and TRU radioactive waste disposal, however, is significantly different from traditional applications. First, the predicted level of residual risk (a maximum of 1,000 cancer deaths in 10,000 years) for a high-level or TRU disposal system is already small. Second, Assurance and Procedural Requirements (e.g., the requirement for multiple barriers) should reduce this residual risk even further. Thus, there is concern by some members of the Subgroup that an "as low as reasonably achievable" (ALARA) type requirement would result in excessively restrictive regulation. In part, this concern about overly restrictive requirements stems from uncertainty about how an "ALARA" type principle would be applied to waste disposal systems. Would it pertain to site selection? Would it be invoked for every design parameter and consideration or only for major engineering components of disposal systems?

One member (Dr. Lash) believes that an ALARA principle should be applied particularly during the site selection process. The Nuclear Waste Policy Act requires DOE to consider more sites than it will characterize in detail, and to characterize more sites that will be needed for disposal initially. In their winnowing process, DOE should be required to consider possible long-term radiological effects.

Given the very high degree of safety provided by the proposed standard, the Subgroup unanimously agrees that any "ALARA" type principle should not be used to increase safety levels for every single aspect of waste disposal system to the maximum extent technologically achievable. The range of opinions within the Subgroup about how, if at all, to apply an "ALARA" like principle is broad, however. If the Subgroup is divided over how to apply this important principle, others probably are as well. We all feel, therefore, that EPA, if it wishes to retain Assurance Requirement (b), should provide more information and clarity about the scope and method for applying an "ALARA" type principle to high-level and TRU waste disposal systems. The purpose of this further analysis would be to show that the proposed requirement would be workable. This information could be included in revised versions of the environmental impact statement and the regulatory impact analysis.

SUMMARY OF RECOMMENDATIONS ON EACH ASSURANCE REQUIREMENT PROPOSED BY EPA

EPA'S PROPOSED ASSURANCE REQUIREMENT	SUBGROUP'S SUGGESTED CHANGE
(a) Waste shall be disposed of promptly once disposal systems are available and the wastes have been suitably conditioned for disposal	Delete.
(b) Disposal systems shall be selected and designed to keep releases to the accessible environment as small as reasonably achievable, taking into account technical, social and economic considerations.	Three members (Drs. Budnitz, Krauskopf and Okrent) would prefer to delete this requirement, but the other member (Dr. Lash) would prefer to retain it.
(c) Disposal systems shall use several different types of barriers to isolate the wastes from the accessible environment. Both engineered and natural barriers shall be included. Each such barrier shall separately be designed to provide substantial isolation.	Reword as follows: "Disposal systems for high-level waste shall use several different types of barriers to isolate the the wastes from the accessible environment. Both engineered and natural barriers shall be included. The barriers shall be designed so that they complement each other and help to compensate for unexpected failures."
(d) Disposal systems shall not rely upon active institutional controls to isolate the wastes beyond a reasonable period of time (e. g., a few hundred years) after disposal of the wastes.	Restrict reliance on active institutional controls to a period of no more than 100 years and require a monitoring program for that period, but no longer.
(e) Disposal systems shall be identified by the most permanent markers and records practicable to indicate the dangers of the waste and their location.	This requirement should be retained, but EPA should provide further guidance for implementation.

EPA PROPOSED ASSURANCE REQUIREMENT	SUBGROUP'S SUGGESTED CHANGE
(f) Disposal systems shall not be located where there has been mining for resources or where there is a reasonable expectation of exploration for scarce or easily accessible resources in the future. Furthemore disposal systems shall not be located where there is a significant concentration of any material which is not widely available from other sources.	Reword as follows: "Places where there has been mining for resources, or where there is reasonable expectation of exploration for scarce or easily accessible resources in the future, or where there is a signficant concentration of any material which is not widely available from other sources shall be deemed unfavorable for location of disposal systems. Such places shall be disqualified as sites for disposal systems unless analysis can demonstrate that favorable characteristics more than compensate for the effects of these unfavorable conditions."
(g) Disposal systems shall be selected so that removal of most of the waste is not precluded for a reasonable period of time after disposal.	Delete.
None.	There should be a requirement that DOE in its site selection process consider potential releases beyond 10,000 years, although the Subgroup could not agree on the detailed wording for this new Assurance Requirement.

APPENDIX A-5

REPORT

of the

GEOCHEMISTRY SUBGROUP

January 17, 1984

Dr. Bruno Giletti, Chairman
Mr. Floyd Culler
Dr. Stanley Davis
Dr. Konrad Krauskopf

GENERAL STATEMENTS

1. Although the EPA models of generic repositories include the concept of multiple barriers for containment of HLW, the principal reliance for isolation of HLW from the biosphere is placed on the slowness of transport through the host geologic medium. To ensure that transport is slow enough so that EPA standards of radionuclide release are met, accurate values of several parameters are needed. The generic repository models that EPA uses, however, involve wide ranges in values for some of the critical parameters such as permeability, solubility, and retardation factors. The large ranges are due partly to uncertainty in experimental data and partly to EPA's effort to encompass all possible lithologies and settings in its generic models.

With site-specific models, the range of possible parameter values for any given lithology and site could be sharply reduced. At a specific site some of the EPA assumptions for the generic model may not hold, and values of some parameters may lie outside the range suggested for the model. For example, solubilities of some elements (notably Tc, Np, U, Pu) are strongly dependent on pH and Eh, and at a particular site might fall outside the range of conservative assumptions built into the EPA model. Also, retardation factors vary markedly with ionic strength. For cesium, as an example, the retardation factor in brine is at least 100 times less than in groundwater of low ionic strength; thus the EPA-chosen value of 1 is reasonably conservative for brines but ultraconservative for other groundwaters. Site specific models would accommodate such differences.

2. Generic repositories in the EPA models all assume that an aquifer exists above, and sometimes also below, the repository, and that such aquifers are saturated with water. In some settings, however, no aquifer exists, or the sedimentary rocks above the repository have low permeability even though they may be saturated. Since isolation and containment are the goals, absence of an aquifer is desirable. Furthermore, at some repository sites the water table is very far below the earth's surface, so that a repository could be placed well above the water table. Such localities have the advantage that little or no water would flow through or near the repository as long as the present hydrologic regime persists. As the principal mode of transport of nuclides from a repository is by dissolution and transport in water, the advantage of these relatively dry sites is obvious. Thus the generic models used in the calculations of repository performance may be excluding a kind of repository setting that is superior to those examined.

3. For a period of several centuries after a repository is charged, the principal sources of radiation will be ^{90}Sr and ^{137}Cs. The modeling assumes that these nuclides will be completely contained for 500 or 1000 years. It should be stressed, however, that any short-circuit of groundwater transport to the biosphere in this early period could cause hazardous releases of strontium and cesium. Siting and

design of a repository should take into account the enormous amount of radioactive material entering the environment that would result if such unanticipated releases occur.

4. All the models used to predict repository performance are based on solubility and retardation-factor data. The models assume the absence of complexing or chelating agents, although such agents, if present, could enhance the transport of radionuclides and cause the release of significantly larger amounts of radioactivity than are predicted by the models. The presence of possible complexing agents will be determined largely by the nature of rocks and groundwaters at the repository site. The chelating agents will probably derive from organic materials introduced during construction, charging, and sealing of the repository. Clearly, the site must be selected and the repository constructed so as to minimize the amounts of such agents.

5. Predictions that geologists and geochemists are asked to make about the future become less reliable as the time period is extended. The reliability of predictions depends somewhat on the kind of waste to be placed in a repository. For reprocessed waste from which uranium and other actinide elements have been largely extracted, the necessary predictions are important chiefly for the first 1000 years, and can be made with considerable confidence. Untreated spent fuel, on the other hand, remains hazardous for tens or hundreds of thousands of years, and predictions for such times are much less dependable.

6. As part of its justification for using 10,000 years as a limit for considering radioactive releases from a repository, EPA notes that by this time the radioactivity of the HLW would have diminished to an amount comparable to that of an unmined uranium ore body. Theoretically the comparison has a good scientific basis, but practically it is questionable because ore deposits are so extremely variable in size, shape, and grade, and their limits and history are so hard to specify. The difficulties are illustrated by EPA's document 520/3-80-009, in which calculated releases from a model ore body are orders of magnitude lower than releases "measured" at actual ore bodies. The comparison is useful in a rough qualitative sense, but a better standard for judging the risk from radioactive releases at the end of 10,000 years would be comparison with the radioactivity of natural waters or the ambient radiation in the general environment.

Recommendation 1

EPA should consider two sets of geochemical parameters for predicting the performance of a repository, one set for high ionic strength environments such as salt, and one for the much lower ionic strength waters that may be expected in other lithologies.

Background for Recommendation 1

The retardation process for ions dissolved in a migrating groundwater involves the adsorption of the ions onto mineral surfaces. If the ion must compete for an adsorption site with large numbers of Na or other ions, it will have a lower probability of being adsorbed. Its retardation factor will then be lower. This would be the case for ^{137}Cs or ^{90}Sr in a brine solution. EPA has chosen retardation factors of 1 for both Cs and Sr. We suggest that 1000 and 200, respectively, would be better numbers, and still be conservative for most lithologies. We would take a value of ten, however, for brines. The EPA value of 1 is acceptably conservative for brines, but is overly conservative for most other lithologies.

Recommendation 2

An addition to section 191.13, Containment Requirements, is recommended. The following would be added to the end of this section:

The choice of sites for these disposal systems shall take into consideration the effects of foreseeable events on releases of radioactive materials beyond the 10,000 year period.

Background for Recommendation 2

The hazard from releases of radioactive material does not decrease sharply at 10,000 years, but will probably continue for periods up to a few million years. A different set of radionuclides becomes important after 10,000 years, particularly those supported by decay of uranium (and other actinides) carried in groundwater. Especially prominent among among these nuclides are ^{226}Ra and ^{210}Pb. Transport of these elements and their uranium parent is governed by different media characteristics and different solubility and retardation factors from those important during the first ten millennia. For example, slightly oxidizing conditions would favor transport of uranium, hence the growth of abundant ^{226}Ra and ^{210}Pb at a distance from the repository, so that the solubility and retardation of these two nuclides become critical to predictions of radioactive releases to the biosphere. Selection of a geologic site and medium for a repository, although still based primarily on predictions for the first 10,000 years, should be influenced also by consideration of the probable behavior of uranium and its progeny.

A second reason for concern beyond 10,000 years is the increasing possibility of geologic disturbance to a repository as time grows longer. One sort of geologic event that might affect the repository is renewed glaciation, unlikely during the the first 10,000 years, but very probable shortly thereafter. Overlying ice would probably not directly damage a repository, but the advance and retreat of ice sheets could cause drastic changes in the hydrologic regime nearby. Even at a considerable distance from the actual glacier, the integrity of a repository could be influenced by the changes in climate, especially precipitation, that would accompany glaciation. Among the geologic factors to be used in siting a repository, consideration should be given to the possibility of glaciation and climate change after 10,000 years.

Recommendation 3

EPA should reassess the values it chose regarding solubility and retardation factors for Am, Sn, Sr, Cs, Tc, and Np.

Background for Recommendation 3

The solubility of Am increases linearly and markedly with decreasing pH. This would imply very high solubilities at pH's less than 6. On the other hand, there is an, as yet, unidentified Am compound that appears to lower the solubility very strongly in some environments at low pH's. Until this compound can be identified and its role assessed in a repository, there is considerable uncertainty in the rate of migration of Am. Owing to this large uncertainty, the EPA estimates for Am may not be conservative.

It is possible that the solubility of Sn is on the order of 0.001 ppm, rather than 1 ppm.

Both Tc and Np solubilities are taken as 0.001 ppm. If the repository conditions, or the aquifer conditions, are not distinctly reducing (Eh less than 0.0 volt), however, solubilities rise markedly. Further, the Tc forms an anion, so that the retardation factor will still be very low as listed by EPA. The results could be a serious underestimate for the Tc release.

For nuclides in non-brine settings, retardation factors used by EPA for Cs, Sr, and Sn may be unrealistically conservative (too small) by one or two orders of magnitude.

Recommendation 4

EPA should acquire good values for solubilities and retardation factors for all the nuclides specifically listed in Table 2 of 40CFR191. The data should be for a range of potential natural conditions, including pH, Eh, temperatures, and different lithologies, where these ranges extend sufficiently beyond the idealized conditions used in the generic models.

Background for Recommendation 4

The EPA effort to establish release requirements that are both safe and attainable requires that it have sufficiently good data to make realistic repository performance estimates. Given the strong dependence on the geological and geochemical barriers, it becomes critical that the transport estimates for the various repository lithologies and aquifers be assessed accurately enough.

The behavior of the nuclides in Table 2 under a variety of pH and Eh conditions is of considerable importance. We point out the strong dependence of solubility on pH or Eh for a number of elements in Recommendation 3. We also note the dependence of retardation factors on the ionic strength of the solution. Modest departures from pH 6-8 or from slightly reducing conditions (EPA generic model assumptions) can make significant differences in solubilities and, therefore, potential releases. Recent observations, that dissolved oxygen has been found in groundwater 300 meters below the saturation zone, point up the need for data when conditions are not slightly reducing.

The data on retardation factors, with some notable exceptions, are based on the interaction of solutions with very few types of solid media, and these are often poorly characterized or inappropriate lithologies. Data from properly designed experiments are few, which leads to uncertainties in how realistic are the repository performance predictions of the generic model, and what degree of conservatism should be introduced in setting standards.

APPENDIX A-6

REPORT

of the

ENGINEERING AND ECONOMICS SUBGROUP

January 17, 1984

Dr. Frank Parker, Chairman
Dr. Robert Budnitz
Mr. Floyd Culler
Dr. Stanley Davis
Dr. Charles Fairhurst

Recommendation 1

To the extent possible and with the data available, EPA should perform an economic analysis (benefit/cost analyses; differential costs and benefits for different levels of protection; and costs for alternate means of disposal). In making this analysis, EPA should use the most current cost models and data now available.

Background for Recommendation 1

Given the data available at the time it was made (early 1982), the analysis is reasonably comprehensive and adequate. It should, however, be made clear in the report that it is valid as of early 1982, since many new data are now available, e.g., ON1-3, PNL-4513, PNL-3949 and the Defense Waste Management Plan.

For a generic, deterministic study the aggregated, simple model used by EPA is adequate for a cost analyses. However, the cost for actual repositories at specific-sites could diverge substantially from these generic costs.

The final costs will not be known until the repository is actually excavated because of the geologic variability certain to be encountered underground. In addition, until the final choice of waste form, package, overpack and backfill is made, the costs will not be defined.

With respect to the EPA cost analysis:

i) We consider it misleading to include costs for storage of spent fuel prior to reprocessing and for transporting the spent fuel to the reprocessing site as a part of the costs for waste management. These costs are associated more directly with energy production than with waste management.

ii) Insufficient distinction is made between management costs that are fixed independent of the volume of waste and those that vary with the throughput and level of protection.

iii) Other disposal strategies, such as extended (i.e., 50 to 100 years) temporary storage of spent fuel or use of extended (over 1,000 years) engineering controls, could result in important changes in costs and benefits, but information available on such strategies is lacking. EPA cost analyses did not consider these questions.

Recommendation 2

Though the uncertainties in the cost estimates are great, the absolute amounts involved are so high that even small percentage savings represent substantial amounts of money. We recommend that EPA carefully examine the possibilities for cost savings in the waste management program.

Background for Recommendation 2

The absolute magnitude of costs involved in the high-level radioactive waste management program are high--many billions of dollars for each repository--and an inevitable consequence of the selection of the deep mined geological option with multiple barriers and associated site selection constraints. The uncertainties in the estimates of waste management costs are also high, typically hundreds of millions of dollars, due mainly to the absence of any comparable prior experience with such a program.

It is important to examine carefully how the proposed EPA standards, and possible modifications, might reduce these large costs even if only by seemingly small percentages, since the absolute number of dollars saved is likely to be large.

Recommendation 3

To disclose the significance of sequencing and delays on site selection and engineering designs of repositories, calculations should consider discounted as well as non-discounted costs for the operational period.

Background for Recommendation 3

Failure to discount costs neglects the major factor of time in the sequence of operations leading to repository emplacement. Discounted cost procedures recognize that expenditures incurred early in repository development are of greater significance than the same amounts expended later. The relative importance of the various cost components in waste isolation could be changed drastically by the use of discounted dollars. For example, storage prior to emplacement in the repository is the largest single cost in the analysis. It is also an early cost. Hence, a rock type that permits early emplacement would reduce storage costs and, on a discounted basis, could dramatically modify the relative cost of storage compared to other components. Costs for research and development (R&D) needed, in part, to demonstrate compliance are also substantial and also come early in the disposal cycle. Again on a discounted basis, R&D costs could become a major factor.

Recommendation 4

We recommend that no type of site should be precluded on the basis of site characteristics alone. Consideration of all factors including engineered barriers, transportation, availability of utilities and labor, etc. may lead to a different choice of sites and isolation technologies than those dictated by site characteristics alone.

Background for Recommendation 4

The constraints on exploration for geological repository sites and the associated long-term containment performance requirements have no counterparts in geological engineering experience. The distance of a repository from radioactive waste production and storage sites is also an important consideration. Consideration of all such factors, including engineering barriers, may lead to preference for sites, all satisfactory, which might possibly be ranked below others when considering geological criteria alone.

Finding 1

Although the actual radionuclide releases from a geologic repository are likely to be less than the proposed EPA release limits, demonstration of compliance with such low release limits will be difficult and for some repository location could result in delays and increased costs associated with such demonstration.

Increasing the proposed limits should not reduce the actual level of protection provided to the public, but could facilitate demonstration of compliance (see also Recommendation 1, Section IV).

Background for Finding 1

The level of protection of public health to be achieved in the disposal of high-level radioactive waste, following the technologies and site types now under active consideration and incorporating the standards and good engineering practices envisaged under EPA, NRC, and DOE requirements, will undoubtedly be high. Assuming that the technologies and media to be used in actual future repositories are chosen from those now under active consideration, the Subgroup believes that, in most cases, the technologies and sites can probably meet the EPA's proposed standard with some margin.

In the range of release limits being considered, the technologies to be used and the major portion of the associated costs are largely independent of the prescribed release limits. However, at the release limits currently envisaged by EPA, the intrinsic variability of geological parameters makes it difficult to demonstrate compliance with reasonable confidence, and will inevitably lead to delays in the compliance demonstration process. Since such demonstration is required at an early stage in the repository development process, these costs assume added importance, especially on a discounted cost basis.

However any drastic increase in the stringency of the currently proposed regulatory requirements could increase costs dramatically (more expensive waste forms and containers), but with essentially no real increase in the level of safety achieved. Recent estimates in the

Swedish KBS plan show that placing heavy reliance on engineered barriers will cost approximately three times as much per MTHM as the current U. S. plan. In fact, such stringencies might lead to disposal situations that would appreciably increase the levels of occupational risks and cost (e.g., in increased handling, transporation, underground emplacement, and administration) without associated public health benefit.

Finding 2

While there are a number of generic cost studies available, there does not appear to have been a definitive study of the R&D costs associated with meeting the performance criteria, or how these would differ for the various rock types, or for different performance criteria.

However, our confidence in the \$11-40/Kg-HM estimates used by EPA is increased by the independent analyses of ONI (Office of National Waste Terminal Storage Integration, DOE) which estimated R&D costs for two repositories to total $\$5 \times 10^9$. Since, as noted earlier, the costs, R&D included, have components that are fixed and others that vary with throughput, the unit costs in the Regulatory Impact Analysis are not constant values. If it is assumed as an approximation that they are constant, the R&D costs for two repositories would range between $\$1.4\text{-}5.6 \times 10^9$.

APPENDIX A-7

REPORT

of the

BIOLOGICAL EFFECTS SUBGROUP

January 17, 1984

Dr. James Neel, Chairman
Dr. Bruce Boecker
Dr. Stephen Kaye

Recommendation 1

When discussing the long-term biological effects produced by the internal or external irradiation of human organs by radionuclides that escape from the repository, EPA should avoid using a term like "health effects" but should refer to the specific category of effects being considered, cancer and/or genetic effects.

Background for Recommendation 1

In the draft EIS and other documents prepared in support of the proposed standard, the term "health effects" is often used when the authors were actually referring to cancer mortality. It is recognized that the analyses have indicated that cancerrelated effects may predominate over genetic-related effects, but this should be emphasized by more precise terminology. In this way, it will be clear what has or has not been included in the final calculations.

Recommendation 2

EPA should continue using the linear, non-threshold dose response model to estimate the possible health effects associated with radioactivity that escapes from the repository.

Background for Recommendation 2

The linear, non-threshold dose response model has been used by a number of scientific bodies that have reviewed the available data on the relationship between dose and the occurrence of long-term somatic and genetic effects. Reports based on the linear, non-threshold dose response model include the BEIR 1972 report, UNSCEAR 1977 report, and part of the BEIR 1980 report and the radiation protection systems recommended by the NCRP and ICRP for occupational situations. In the case of the majority BEIR 1980 report, a linear non-threshold model was used for high LET radiation; for low LET radiation, a linear model was selected for upper bound estimates of risk, and a linear-quadratic model for best estimate determinations. The true risk was postulated to range from the values of estimates from the dose-response model to, perhaps, zero. The BEIR 1980 report indicated also that no judgment was being made on the shape of the dose-response curve below 100 mrem, as supporting data were not available.

What are the consequences of choosing a linear, non-threshold dose response model for assessing the long-term somatic and genetic effects of radioactivity that escapes from a repository? On the positive side, this particular dose response function facilitates the calculation of population effects. Since the risk of long-term somatic or genetic effects per unit dose is currently thought to be constant regardless of the level of dose received, the risk to an irradiated population can be determined from the average population dose without knowledge of the distribution of dose within the population. Since all increments of dose received are accorded the same risk per rem, the use of a linear, non-threshold dose response model is generally considered to be a conservative practice that will not underestimate the possible consequences. In the present case, which involves the multiplication of microdoses by megapeople, it is very possible that such a calculation will actually overestimate the resulting effects by a large amount. There seems to be no realistic alternative at the present time to the linear model.

These calculations require the extrapolation of a dose response relationship many orders of magnitude from the dose region in which actual effects were noted to the very low doses projected in the current waste disposal analyses. When dose response functions of different shapes are used for this purpose, greatly differing risk values are obtained. There are no effects data available for these very low doses, and it is unlikely that epidemiological data will ever be available to assess the appropriateness of different dose response models in the very low dose region. Thus, the use of any dose response model for the present purpose involves a high degree of speculation, and the values obtained have very little merit as absolute indicators of the number of biological effects that may occur. They do serve a useful purpose, however, by providing a relative yardstick by which different repository designs and sites can be compared and evaluated.

Recommendation 3

EPA should adopt a set of health risk factors that are clearly traceable to some recognized set of health risk factors, and they should clearly document the reason for any exceptions.

Background for Recommendation 3

The current Environmental Impact Statement (EIS) and other documents supporting the proposed standard contain a health risk factor for different body organs expressed as the risk of cancer (or genetic effects for gonad irradiation) per rem of absorbed dose equivalent. This list is an accurate reflection of the current knowledge as to which tissues are more important in this regard. However, the numerical values are not directly traceable to any particular set of risk factors as presented by advisory bodies such as the BEIR 1972, BEIR 1980, or ICRP 1979 reports. It is recognized that as new data become available, there may be changes in the values given in a list such as this. However, for the present purposes, it seems that the credibility of the calculation would be enhanced by using a set of risk estimates derived by one or several of these recognized advisory bodies.

Recommendation 4

When considering the genetic effects in future generations, the effects to all generations should be computed, not just those to the first generation.

Background for Recommendation 4

Inasmuch as the somatic effects are calculated generation-by-generation, symmetry requires the same for the genetic. However, the genetic differ from the somatic in that they are cumulative. Otherwise stated, since the cancers are eliminated by the death of the affected persons, they will not accumlate, but since a mutation will produce an allele which may be transmitted from generation to generation, genetic effects will cumulate, up to some "equilibrium" figure. The rate of accumulation and the final equilibrium value depend on the average handicap imposed by the mutant gene. Even though per generation the genetic effects are less than the somatic, by the end of 10,000 years the genetic level per generation could be as great as the somatic. The relationship between mutation (m), selective disadvantage (s), and frequency (f) is given by the very simple relationship

$$f = m/s$$

If the mutations induced by radiation confer an average selective disadvantage of 0.5, then at equilibrium (largely achieved in 10 generations), the traits will be twice the mutation rate in frequency. If, however, medical care alleviates the average impact of these mutations, to where the average selective disadvantage is only 0.1, or even 0.01, then the equilibrium frequencies become 10 or 100 times the mutation rate, respectively.

Recommendation 5

When stating the health risk numbers, a best value with possible uncertainty of a range of possible values should be given instead of single values, as is done now.

Background for Recommendation 5

There are two main areas of uncertainty in these risk estimates. The first relates to uncertainty in the relationship between dose and response in the region for which data exist (relatively high doses obtained at relatively high dose rates). The second relates to the dose response projection model used to extrapolate to very low doses resulting from very low dose rates. The uncertainty associated with the former can and should be addressed in the table of listed risk factors. The latter case may involve a very large range of errors associated with an extrapolation into a region where it is not known whether the chosen dose response function is applicable. Trying to assess uncertainty in this region would be very subjective and unproductive for the purpose of these calculations. However, the report should indicate that an extrapolation two orders of magnitude beyond well-studied dose effects is involved, and, in the case of genetic effects, from a mouse model which may not be appropriate in all respects.

Recommendation 6

The EPA should emphasize more strongly than at present that the health effects being calculated result from radiation exposure which, as the situation is now understood, would have resulted at least in part from the unmined ore itself, i.e., natural weathering of ore and transport of uranium and daughter products via erosion, groundwater, surface water, wind, etc.. In this case, these phenomena result in substitutional rather than additive health effects.

Background for Recommendation 6

EPA has made this statement in EPA 520/3-80-000 and in the Federal Register 47:858203 (29 December 1982); we are concerned that this inference not be lost sight of or buried in the final document.

APPENDIX B

40 CFR Part 191 (Proposed)

Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes.

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 191

[A–FRL 1810–1]

Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes

AGENCY: Environmental Protection Agency.

ACTION: Proposed rule.

SUMMARY: The Environmental Protection Agency requests comments on proposed environmental standards for the management and disposal of spent nuclear reactor fuel and high-level and transuranic wastes. Subpart A of the proposed standards would limit the radiation exposure of members of the public from management of spent fuel and of waste prior to disposal. Subpart B would establish both containment requirements for disposal systems and requirements to assure that these containment requirements should be met. The containment requirements would limit the amount of radioactivity that may enter the environment for ten thousand years after disposal. The assurance requirements provide seven principle necessary for developing confidence that these long-term containment requirements will be complied with. The requirements of Subpart B would apply to disposal by any method, except disposal directly into the oceans or ocean sediments.

After we consider the comments received on this proposal, we will develop a final version of these standards and promulgate them as a new Part 191 to Title 40 of the Code of Federal Regulations (40 CFR Part 191). The standards would be implemented by the Nuclear Regulatory Commission and the Department of Energy under their respective statutory responsibilities.

DATE: Public hearings on this proposed rule will be held during May of 1983. Specific dates and arrangements will be announced in a later Federal Register notice. Comments on the proposed rule and requests to participate in the public hearings should be received on or before May 2, 1983.

In addition, a panel of EPA's Science Advisory Board (SAB) will review the technical analyses supporting the proposed standards during the comment period. The meetings of the SAB panel will be open to the public and will be announced in the Federal Register.

ADDRESS: Comments should be submitted (in duplicate if possible to: Central Docket Section (A–130), Environmental Protection Agency, Attn: Docket No. R–82–3, Washington, D.C. 20460.

Docket No. R–82–3, containing material relevant to this rulemaking, is located in the West Tower Lobby, Gallery 1, Central Docket Section, Environmental Protection Agency, 401 M Street, S.W., Washington, D.C. The docket may be inspected between 8 a.m. and 4 p.m. on weekdays, and a reasonable fee may be charged for copying.

Single copies of the Draft Environmental Impact Statement for this action may be obtained by writing to: Director, Criteria and Standards Division (ANR–460), Office of Radiation Programs, Environmental Protection Agency, Washington, D.C. 20460.

Requests to participate in the public hearings should be made in writing to the Director, Criteria and Standards Division. All requests for participation must include at least an outline of the topics to be addressed in the opening statement(s), the amount of time requested for the statement(s), and the names of the participants. Statements should not repeat information already presented in written comments, but should address additional information or issues.

FOR FURTHER INFORMATION CONTACT: Daniel Egan, telephone number (703) 557–8610.

SUPPLEMENTARY INFORMATION: Fissioning of nuclear fuel in nuclear reactors creates a small quantity of highly radioactive materials. This concentrated radioactivity is retained in the spent fuel elements when they are removed from the reactor. If the fuel is then reprocessed to recover unused uranium and plutonium, the concentrated radioactivity goes into acidic liquid wastes that will later be converted into solid forms. These highly radioactive liquid or solid wastes from reprocessing spent nuclear fuel, or the spent fuel elements themselves if they will be disposed of without reprocessing, are called "high-level wastes." The nuclear reactors operated by the nation's electrical utilities currently generate about 2,000 metric tons of spent fuel per year. For comparison, chemically hazardous wastes regulated under the Resource Conservation and Recovery Act are produced at a rate of about 40,000,000 metric tons per year.

Although they are produced in small quantities, proper management and disposal of high-level wastes are important because of the inherent hazards of the large amounts of radioactivity they contain. This need for careful control has been recognized since the inception of the nuclear age. The Federal Government has always assumed responsibility for the ultimate care and disposal of these wastes, regardless of whether they are produced by commercial or national defense activities. Over the last several years, the Federal Government has intensified its program to develop and demonstrate a permanent disposal method for high-level wastes. President Reagan's April 28, 1982 message to Congress on nuclear waste disposal reaffirmed this commitment and called for a Federally-owned and operated permanent repository to be available at the earliest practicable date. The environmental protection requirements that we are proposing today will provide the basic framework for the long-term controls that these wastes need.

High-level wastes contain many different radionuclides. Some of these nuclides emit alpha particles; other emit beta particles. Some radionuclides emit gamma rays in addition to alpha or beta particles. The radionuclides decay with half-lives ranging from less than one year to millions of years. We have concentrated our attention on radionuclides with half-lives greater than 20 years because they must be isolated from people for very long times. Thus, we exclude radionuclides such as tritium, krypton-85, and plutonium-241, which are present in large quantities in freshly discharge fuel, but which decay so rapidly that they do not require long-term isolation.

Reprocessing reactor fuel used for national defense activities has produced about 500 million curies of radionuclides with half-lives greater than 20 years. Most of the activity is due to strontium-90 and cesium-137, which have half-lives of about 30 years. These wastes are stored in various liquid and solid forms on three Federal reservations in Idaho, Washington, and South Carolina. Relatively small additions are being made from ongoing defense programs.

Spent fuel from commercial nuclear power reactors contains about 800 million curies of radionuclides with half-lives greater than 20 years. About 10 million curies of this radioactivity are due to radionuclides, such as plutonium, which emit alpha particles. Most of this spent fuels is stored at reactor sites. Over the next few years, this inventory is expected to grow at a rate of about 200 million curies per year from reactors currently licensed to operate. At some reactor sites, spent fuel storage capacity is almost used up. Electrical utilities, the operators of commercial reactors, are pursuing a variety of techniques to increase storage capacities, and legislation concerning Federal assistance for spent fuel storage is under consideration in Congress.

Nuclear reactors use some isotopes of uranium, plutonium, or thorium to produce energy from nuclear fission. These elements are sometimes referred to as "heavy metals." The amount of wastes produced is roughly proportional to the amount of these elements placed into a reactor. We use the unit "wastes generated per metric ton of heavy metal (MTHM)" to measure the amount of waste placed in disposal systems.

The amount of natural uranium ore needed to produce one MTHM depends on the reactor type, degree of reprocessing, and quality of ore. For the light water reactors currently used in the United States, about 6,000 metric tons of uranium ore are used to produce one MTHM of reactor fuel. We have used this relationship to associate amounts of waste from reactor fuel with uranium ore.

In proposing these environmental protection requirements, we do not advocate any specific method for disposing of high-level wastes. However, in developing our proposed standards, we considered the long-term risks from disposal in mined geologic repositories. We concluded that well-designed repositories at well-chosen sites can keep potential radiation exposures to very low levels. In fact, because repositories appear to provide such good protection, we have chosen to propose disposal standards that limit the risks to future generations to a level no greater than the risks which those generations would be exposed to from equivalent amounts of unmined uranium ore. Thus, any risks to future generations from disposal of high-level wastes would be no greater than, and probably much less than, risks which those generations would face if the wastes had not been created in the first place.

Description of the Proposed Action

Under authorities established by the Atomic Energy Act and Reorganization Plan No. 3 of 1970, we are proposing generally applicable environmental standards for managing and disposing of these wastes. When such standards are promulgated, the Nuclear Regulatory Commission (NRC) and the Department of Energy (DOE) will be responsible for implementing and enforcing them through appropriate regulations and procedures. The Draft Environmental Impact Statement (EIS) published with this proposal includes detailed discussions of the reasons for our selections of these standards, and it provides extensive summaries of the technical analyses used. This preamble describes our proposed action, highlights features that we believe are of major interest, and points out issues on which we particularly seek public comment.

The proposed standards apply to spent reactor fuel, the highly radioactive wastes derived from reprocessing spent fuel, and to certain wastes containing long-lived radionuclides of elements heavier than uranium ("transuranic wastes"). Transuranic wastes are covered if they contain 100 nanocuries or more of alpha-emitting transuranic isotopes, with half-lives greater than 20 years, per gram of waste. People could receive, under some circumstances, more than 500 millirems per year from wastes containing more than 100 nanocuries of transuranic elements per gram if these wastes were not well isolated. 500 millirems per year is the Federal Radiation Protection Guide for individuals in the general population. Because transuranic wastes have very long half-lives and represent a potential hazard for very long times, we are proposing the same controls for these wastes as would be required for high-level wastes. Protection requirements for transuranic wastes containing less than 100 nanocuries per gram will be considered in future standards.

Some wastes produced from reprocessing spent fuel, particularly when changing the form of the wastes, may not need the same degree of control as the high-level wastes themselves. (For example, processing of certain defense wastes may leave large volumes of salt cake containing relatively low concentrations of technetium-99.) Accordingly, we are proposing a definition of high-level waste that would exclude wastes that contain less radioactivity than the concentration levels specified in Table 1 of the standards. Disposal of wastes with less radioactivity will be considered in future standards.

The levels in Table 1 are equivalent to the maximum concentrations for acceptance at shallow-land burial sites that the Nuclear Regulatory Commission (NRC) will soon promulgate as part of 10 CFR Part 61. The concentration limits in 10 CFR 61 have been derived so that a person intruding into a shallow-land site, after institutional controls were no longer effective, should not receive a radiation exposure greater than 500 millirem per year. However, because no method to generically classify radio active wastes by their need for isolation has been widely accepted yet, we particularly seek comment on our proposed definition of high-level waste.

The proposed standards do not apply to wastes that have already been disposed of. Although no high-level wastes have ever been disposed of in this country, some transuranic wastes have been buried at a number of sites. Most of these wastes, produced in support of national defense programs, were disposed of before the current Department of Energy (DOE) procedures for transuranic waste management were adopted in 1970. We do not currently have enought information on costs and risks to develop generally applicable standards for these wastes.

Also, our standards do not apply to ocean disposal because such disposal of high-level waste is prohibited by the Marine Protection, Research, and Sanctuaries Act of 1972.

In developing the proposed standards, we estimated the risks from waste management and disposal systems that use methods of controlling releases which either are available now or are likely to be available in the near future. From these evalnations, we concluded that:

1. Any harm to people, including future generations, from the management and disposal of spent fuel, high-level, and transuranic wastes can be kept very small. The assessments which support this conclusion are outlined below and are discussed extensively in the Draft EIS.

2. The standards that we are proposing would adequately protect the public from harm. Under them, the risks to future generations from the wastes would be no greater than the risks from equivalent amounts of unmined uranium ore. These risks would also be far less than the risks from other sources of natural background radiation.

In selecting the release limits given in the standards, we projected the performance of disposal systems which have not yet been demonstrated. There are significant uncertainties inherent in such projections. To avoid underestimating the risks associated with such systems, we often made pessimistic assumptions about how well a repository would perform. For example, we assumed that human intrusion into a repository would take place as if no site markers or records discouraged it beginning 100 years after disposal. Our estimates may, therefore, be considered upper bounds of the risks. When actual control methods are selected and demonstrated at specific sites, expected releases are likely to be well below the amounts allowed by the proposed standards. Accordingly, the proposed standards instruct the implementing agencies to take steps to reduce releases below these upper bounds to the extent reasonably achievable, taking into account technical, social, and economic considerations.

Our environmental standards apply to both management and disposal. Subpart A applies to management and includes storage, preparation of the wastes for disposal, and placing them in a disposal site. Off-site transportation is not covered. In his April 28, 1982 message to Congress, President Reagan recommended that both temporary storage facilities and long-term, monitored retrievable storage (MRS) facilities be considered to manage spent fuel and high-level waste until a permanant repository is available. Subpart A would apply to both types of storage systems. Subpart B applies once the wastes are isolated enough so that it would be much harder to get them out of a disposal system than it was to put them in. With a geologic repository, for example, Subpart B would take effect when the mine was backfilled and sealed.

Waste Management

(40 CFR Part 191 Subpart A)

Certain operations required before disposing of high-level or transuranic radioactive wastes are not regulated under our Uranium Fuel Cycle Standards (40 CFR Part 190). These operations principally involve storage of the materials, solidification or other preparation for disposal, and placing the wastes in disposal sites. Subpart A applies to spent fuel management, regardless of whether the fuel is considered to be waste or is destined for reprocessing, except for management already regulated by 40 CFR Part 190.

We estimated the largest expected radiation exposures to members of the public from waste management and storage operations associated with geologic disposal and found them to be somewhat smaller than the requirements set in 40 CFR 190. We propose to extend the limitations contained in Part 190 to the operations addressed by this new Part 191 for two reasons:

1. Some strategies for disposal could involve operations, such as chemical separation of transuranic elements, which are similar to those of spent fuel reprocessing. Reprocessing operations were a significant consideration in selecting the limits of 40 CFR 190. Setting the standards in Part 191 at the levels indicated by assessments based only on geologic disposal activities could preclude other disposal strategies which might be better overall.

2. Some of the operations addressed by Part 191 may take place near operations regulated by Part 190. Establishing different limitations for different operations at the same site would create difficult implementation problems with little, if any, additional public health protection. The provisions of Part 191 require the combined impacts from multiple operations to meet a single set of dose limitations which will be the same in both Parts 190 and 191.

Section 191.03 therefore requires that the combined annual dose equivalent to any member of the public due to operations covered by Part 190, and to direct radiation and planned discharges of radioactive materials covered by this Subpart, shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ. It also requires that waste management operations be conducted so as to reduce exposures for members of the public below this level to the extent reasonably achievable, taking into account technical, social, and economic considerations.

Disposal

(40 CFR 191 Subpart B)

Environmental protection standards for the disposal of high-level and transuranic radioactive wastes require far different considerations than those for management. These include the following:

1. The intent of disposal is to isolate the wastes from the environment for a longer time than any period over which active controls, such as monitoring the disposal site to detect releases of radioactivity, can reasonably be relied upon for protection.

2. These disposal systems will be designed so that very little, if any, radioactivity returns to the environment if the system performs as intended. Thus, the principal concern is the possibility of accidental releases, either due to unintended events or due to failure of parts of the disposal system to perform as expected.

These considerations have several ramifications for developing environmental protection standards. First, the requirements we establish can only be implemented by the NRC and DOE in the design phase—by setting design principles or by analytically projecting disposal system performance. The more familiar concepts of implementation involving monitoring of emissions or ambient levels of pollutants are not applicable because such surveillance cannot be relied upon for the long time periods involved.

Second, the standards must address unintentional releases such as those resulting from human intrusion or geologic faulting. Their provisions must be applicable to a variety of disposal strategies because the Agency does not have the authority to specify details of disposal method designs. Regulations to be developed by the NRC or DOE, as appropriate, will control specific designs.

Third, the standards must accommodate large uncertainties. These include both uncertainties in our current knowledge about disposal techniques and inherent uncertainties about the distant future. Thus, protecting the environment involves encouraging use of disposal systems that are tolerant of potential mistakes in engineering design or site selection.

We addressed these issues by developing numerical containment requirements for disposal systems accompanied by qualitative requirements to assure that these containment requirements should be met. These two parts of our proposed action are complementary: the containment requirements set limits on potential releases of radioactive materials from disposal systems for 10,000 years after disposal; the assurance requirements provide the framework necessary to develop appropriate confidence in meeting the containment requirements in spite of the inherent uncertainties. In addition, the standards contain procedural requirements to insure that the containment requirements are properly applied.

Containment Requirements

(Section 191.13)

To develop the long-term containment requirements, we assumed that we can predict some aspects of the future well enough to use the predictions for comparing and selecting disposal methods. Thus, we evaluated ways that waste might be released from a mined geologic repository, developed analytical models to predict potential releases and their distribution throughout the ecosystem over 10,000 years, and estimated the possible risks that could result from these releases if they occured in an environment similar to today's.

We concentrated on geologic repositories because much more information is available on this approach than on other disposal methods, and because the Department of Energy has decided to focus the national program on this method (46 FR 26677). Furthermore, when we evaluated the limited information available on other disposal methods, we did not identify any other methods which were clearly better than geologic disposal. Our disposal standards, however, are meant to apply to any method of disposal, except disposal directly into the ocean or ocean sediments. Thus, any other disposal method would have to provide at least as much protection as that projected for geologic disposal.

There are significant uncertainties in the analytical models are used to assess the long-term performance of geologic repositories, and there are substantial uncertainties in the data we used in the models. The primary objective of the review to be conducted by the Agency's Science Advisory Board will be to judge whether our models and assumptions are adequate for the purpose they served in our development of containment requirements. The following paragraphs more fully describe how we formulated these requirements.

In our assessments of geologic disposal, we identified expected and accidental releases of radioactivity from a generic model of a repository. The model repository contains 100,000 MTHM of spent reactor fuel, about as much as would be generated during the operating lifetimes of 100 reactors of current design. The initial amounts of some of the principal radionuclides in this model repository would be: eight billion curies of cesium–137; six billion curies of strontium–90; 200 million curies of americium–241; 30 million curies of plutonium–239; and one million curies of technetium–99.

We examined the capabilities of waste canisters, waste chemical forms, repository design, and geologic media to prevent or delay the release of radionuclides. We selected reasonably achievable characteristics for each portion of the disposal system. For accidental releases, we estimated the probabilities of events leading to releases. Intentional disruption of the disposal system was not considered.

Radionuclides were considered to be released from the disposal system if they reached the "accessible environment," which includes surface waters, land surfaces, the atmosphere, and the oceans. Our definition of the "accessible environment" also includes all groundwater formations that are more than ten kilometers in any direction from the original location of the radioactive wastes in a disposal system. Although this approach does not provide any direct protection for the relatively small amount of groundwater that could within ten kilometers of a geologic repository, it recognizes that adjacent geologic formations serve as part of the containment system for a repository. Since the amount of groundwater left unprotected should be kept as small as possible, consistent with other requirements, we expect that the Federal environmental impact statement for each disposal system will identify all sources of groundwater within ten kilometers of the disposal system, will describe the potential long-term environmental effects of possible contamination of these sources of groundwater, and will consider these effects as one the factors in evaluating alternative sites.

Our regulations and the assessments on which we base them cover releases of radionuclides to the accessible environment for a period of 10,000 years after disposal. We believe that a disposal system capable of meeting these requirements for 10,000 years will continue to protect people and the environment beyond 10,000 years. We selected 10,000 years as the assessment period for two reasons:

1. It is long enough for releases through groundwater to reach the accessible environment. If we had selected a shorter time, such as 1,000 years, our estimates of long-term risks in the accessible environment would be deceptively low, because groundwater could take 1,000 years to travel a mile at a well-selected site, and most radionuclides would take much longer. Choosing 10,000 years for assessment encourages selection of sites where the geochemical properties of the rock formations can significantly reduce releases of radioactivity through groundwater.

2. Major geologic changes, such as development of a faulting system or a volcanic region, take much longer than 10,000 years. Thus, the likelihood and characteristics of geologic events which might disrupt the disposal system are reasonably predictable over this period.

We estimated the amounts of radioactivity that could reach the accessible environment over this time period under various circumstances. Releases from geologic repositories fall into three general categories. Relatively small releases would be caused by expected processes and by fairly likely but unintended events. These processes and events lead to what we call "reasonably foreseeable" releases. Moderate releases would result from much less likely events, such as fault movements or other disruptive geologic events and these we call "very unlikely releases." Very large releases would result only from the intrusion of volcanos or impacts by huge meteorites. If sites are selected away from regions of volcanic activity, these large releases will be extremely unlikely.

We used our estimates of releases and their likelihood to select limits on total releases of radioactivity over 10,000 years. Limits were set for two categories of releases in terms of their probabilities: "reasonably foreseeable," and "very unlikely." The release limits for the "very unlikely" category are ten times larger than those for the "reasonably forseeable" category. Reasonably forseeable releases are those which have more than one chance in 100 of occurring within 10,000 years. Very unlikely releases are those whose chance of occurring within 10,000 years is less than one in 100 and more than one in 10,000. No limits were set for releases which have less than one chance in 10,000 of occurring within 10,000 years.

To select the specific release limits for the various radionuclides in a disposal system, we first estimated the health effects that might be caused by these releases. For these calculations, we used very general models of environmental transport and a linear, nonthreshold dose-effect relationship between exposure and premature deaths from cancer. This relationship, which is based on studies prepared by the National Academy of Sciences (NAS), assumes that the number of cancers induced in a population is proportional to the total dose received by the population, even at very low individual doses. At the low levels of exposures that might be associated with releases from a mined geologic repository, any actual incidence of health impacts may be less than that calculated by this relationship, and it certainly would not be distinguishable from natural occurrences of cancer. However, the Agency believes that health impact estimates using a linear, nonthreshold relationship are a prudent consideration in developing radiation protection requirements.

Our assessments of repository performance gave estimates of the possible health effects expected from releases after disposal. These estimates can vary considerably depending upon the assumptions used and the geologic media considered. For well-designed 100,000 MTHM model repositories in salt and granite—using engineering controls that we believe are readily achievable—we estimate that the health risks over 10,000 years would be no greater than the risks from an equivalent amount of unmined uranium ore. To provide a specific basis for our proposed standards, we selected a limit on long term risks of 1,000 health effects over 10,000 years for a 100,000 MTHM repository. Our assessments show that a wide variety of repository designs and sites can reduce risks below this level. We then used this level of protection as the basis for calculating the release limits specified in Table 2 of the standards.

According to our models, at well-chosen repository sites more of the projected risk from releases is due to possible human intrusions than from releases by geologic processes—if we make the very conservative assumption that passive institutional controls have no effect in deterring or limiting inadvertent human intrusion for more than 100 years after disposal. However, predicting human actions is much more uncertain than predicting natural events. In particular, we can only guess at the frequency of some actions (such as drilling for resources). We considered setting separate containment requirements that would limit the radioactivity that could be released by any one likely human intrusion, in order to avoid having to estimate such frequencies. However, we did not do this because: (1) setting separate requirements for natural and human events would not place an upper limit on risk; and (2) setting separate requirements for individual intrusions in addition to the total combined requirements would not appreciably increase confidence that the overall requirements would be met unless we made the limits on individual intrusions unreasonably low.

The release limits are given in Table 2 in terms of curies released per 1,000 MTHM. The release limit for each radionuclide is the number of curies of that radionuclide that we estimate could cause 1,000 health effects over 10,000 years if it were the only radionuclide released from a 100,000 MTHM repository. For releases involving more than one radionuclide, the allowed release for each radionuclide is reduced to the fraction of its limit that insures that the overall limit on harm is not exceeded. For transuranic wastes, the release limits are in terms of curies released from units of an amount of wastes containing one million curies of alpha-emitting transuranic radionuclides. These units were chosen so that the standards would require alpha-emitting radioactivity from either high-level or transuranic wastes to be isolated with about the same degree of effectiveness. This procedure for using the release limits is described in Table 2 to the proposed standards. Compliance with these containment requirements will be achieved if the projected releases from a disposal system do not exceed these release limits.

Assurance Requirements

(Section 191.14)

Closely associated with our numerical containment requirements are seven qualitative requirements we believe are essential for developing the needed confidence that our long-term release limits should be met. These assurance requirements address and compensate for the uncertainties that necessarily accompany plans to isolate these dangerous wastes from the environment for a very long time. No matter how promising analytical projections of disposal system performances appear to be, high-level and transuranic wastes should be disposed of in a cautious manner that reduces the likelihood of unanticipated releases. Our assurance requirements provide the context necessary for application of our containment requirements, and they should insure very good long-term protection of the environment.

Several of the concepts incorporated in these assurance requirements have been adapted from the Federal Radiation Protection Guidance for all types of radioactive waste disposal that we proposed for public comment on November 15, 1978 (43 FR 53262). After reviewing the responses we received, we decided that the characteristics of different kinds of radioactive waste are not sufficiently similar for generally applicable criteria to be appropriate. Therefore, we stopped developing this Federal Radiation Protection Guidance (48 FR 17387). However, we also determined that, because of the uncertainties inherent in 10,000-year containment requirements, several of the principles included in this earlier proposal needed to be incorporated as integral parts of these standards for disposal of high-level and transuranic wastes.

The seven assurance requirements in Section 191.14 include the following principles. We expect that the specific steps taken by the implementing agencies to comply with each of these requirements will be described in the Federal environmental impact statement—and other appropriate decision documents—for each disposal system.

1. These wastes shall be disposed of promptly once adequate methods are available in order to reduce the chance of accidents during long-term storage. We have not established a time limit for this requirement because the appropriate length of storage may depend on details on the disposal method. For example, it may be desirable to store high-level wastes for ten years or more to allow for decay of most of the short-lived radionuclides. The primary intent of this requirement is to prevent wastes from being stored indefinitely in order to avoid ultimate disposal.

2. Because they must be effective for so long, disposal systems shall offer as much protection as is reasonably achievable. Confidence in complying with the numerical release limits can only be assured through adopting this approach. There will always be substantial uncertainties in predicting the long-term performance of these systems, and a conservative approach to site selection and system design is essential to reduce the chances of serious harm. This concern, of course, must be balanced by judgments about cost, technical feasibility, and social considerations. Although the intent of the requirement cannot be reduced to a quantitative form, it is a concept that has been successfully applied to radiation protection matters for a long time.

3. Disposal systems shall reduce the consequences of possible mistakes in selection, design, or construction by using several different types of engineered and natural barriers against release of the wastes, and by taking full advantage of the protection each has to offer. With this redundancy, the unexpected failure of one or more barriers will be compensated for by other barriers. Different kinds of engineered barriers may be appropriate, depending upon the type of waste involved. They could include canisters, the physical and chemical forms of the waste itself, waste package overpacks, or other structures within the disposal system that will prevent or substantially delay release of the waste to the environment.

4. Protection from the wastes shall not depend on people to take active measures to control them for more than a reasonable period of time after disposal, although the Federal Government plans to retain perpetual control over all disposal sites for high-level wastes. The appropriate role for institutional controls was discussed extensively during the development and public review of the Federal Radiation Protection Guidance for radioactive waste disposal that we proposed on November 15, 1978 (43 FR 53262)—since one of those Guides would have limited reliance on institutional controls for not longer than 100 years. Public comments

on this issue were divided fairly evenly among four positions: (1) That institutional controls should be relied upon for only about one generation, or 20–30 years; (2) that the 100-year period was appropriate; (3) that the 100-year period should be extended to 500–1,000 years or even longer; and (4) that we should limit reliance on controls, but let the implementing agencies select the appropriate period. Several commenters also made a distinction between "active" controls, such as restricting access to disposal sites, and "passive" controls, such as warning markers and records.

In these assurance requirements for high-level and transuranic radioactive waste disposal, we have decided to limit reliance on "active" controls—such as guarding a disposal site, performing maintenance operations, or controlling or cleaning up any releases from a site—to a "reasonable" period of time after disposal, which we believe should be no more than a few hundred years. However, because the Federal Government is committed to retaining control over these disposal sites in perpetuity, we expect that "passive" institutional measures should substantially reduce the chance of inadvertent human intrusion well beyond this period. Such passive controls will include permanent markers placed at a disposal site, public records or archives, Federal ownership or control of land use, and other methods of preserving knowledge about the disposal system. The assumptions that we believe are appropriate when considering the effectiveness of passive institutional controls are described in our procedural requirements (§ 191.15). These proposed provisions regarding institutional controls only apply to disposal of high-level and transuranic wastes and are not intended to have implications for regulations regarding other radioactive wastes. We particularly seek comment on all of our provisions regarding institutional controls.

5. The dangers and locations of disposal systems shall be recorded in the most permanent ways practicable in order to reduce the chances of unintended disruption of disposal systems by future generations.

6. Disposal systems shall not be located where there has been mining for resources, or where there is a reasonable potential for future exploration for scarce or easily accessible resources. Furthermore, disposal systems shall not be located where there is a significant concentration of any material which is not widely available from other sources. This requirement would discourage the use of geologic formations which are often associated with resources or mining activity. For example, the frequent mining of salt domes either for their relatively pure salt or for use as storage caverns would argue against locating a repository in this type of structure. However, this same concern would generally not apply to bedded salt deposits because they are much more common. We particularly seek comment on this requirement because it could rule out sites which might otherwise be advantageous in meeting all of our other requirements.

7. Recovery of most of the wastes should not be precluded for a reasonable period after disposal if unforeseen events require this in the future. The various isolation requirements of these standards would make recovery after disposal very difficult and expensive and probably dangerous. Nevertheless, because some of our scientific understanding may prove to be wrong in a way that would produce much greater risks than we expect, future generations should be able to recover the wastes if they deem it essential. An important implication of this requirement is that the physical location of most of the wastes must be reasonably predictable after disposal. Current plans for mined geologic disposal would meet this requirement. However, some possible disposal methods, such as deep well injection of liquid wastes or rock melting concepts, may not. Since this requirement could eliminate some otherwise feasible and perhaps advantageous disposal methods, we particularly seek public comment about it.

Procedural Requirements

(Section 191.15)

The containment requirements in § 191.13 were derived with the assistance of our performance assessments of long-term repository performance. When these requirements are applied to a particular disposal system, some of the procedures we used in our assessments must be retained to insure that the intent of our containment requirements is met. On the other hand, some of the assumptions we made should be replaced with the specific information developed for each particular system. The requirements in § 191.15 establish the procedures necessary for proper application of our containment requirements.

We based our performance assessments on relatively simple models of generic repositories and the data that was available for such models. Where information was uncertain, we made conservative assumptions that should tend to overestimate the long-term risks of disposal. However, we do not intend that the implementing agencies should use all of the same models, data, and assumptions that we did in making performance assessments. Instead, the implementing agencies generally should use the best information available for each particular disposal site.

In particular, the assumptions we made about the frequency of human intrusion were conservative because they ignored the substantial protection that passive institutional controls should offer. The performance assessments made for specific sites by the implementing agencies do not need to be as pessimistic with regard to human intrusion. Because of the uncertainties of controls requiring the active participation of people over a long time, performance assessments should not assume that active institutional controls can prevent or reduce releases beyond a reasonable period of time (e.g., a few hundred years) after disposal. However, because the Federal Government is commited to retaining control over these disposal sites in perpetuity, passive institutional controls should substantially reduce the chance of inadvertent human intrusion well beyond this period. These passive controls should not be assumed to prevent all possibilities of inadvertent intrusion, because there is always a chance that the controls will be overlooked or misunderstood. However, such measures should be effective in deterring systematic or persistent exploitation of a disposal site. Furthermore, the chance of human intrusion should be very small as long as the Federal Government retains passive control of disposal sites.

In developing the standards for disposal, we considered the overall protection which should be achievable by the combination of barriers in a geologic repository. Accordingly, the analyses used by NRC and DOE to evaluate compliance with our requirements should consider realistic assessments of the protection provided by all of the engineered and natural barriers of a disposal system. For example, performance assessments of a geologic repository system should include the protection afforded by geochemical retardation of radionuclides and by the limited solubility of radionuclides in groundwater, provided that reasonable evidence is developed to support such mechanisms for that particular site.

Implementation

The standards for waste management operations (Subpart A) will be implemented by the NRC for commercial nuclear power activities and by the DOE for national defense facilities. Implementation procedures for Subpart A will be very similar to those for the Uranium Fuel Cycle Standards (40 CFR Part 190).

The standards for disposal (Subpart B) will be implemented by the NRC for all high-level wastes, whether the wastes come from commercial or military activities. The NRC will do this by developing the necessary regulations (primarily 10 CFR Part 60) and by issuing appropriate licenses. Under current law, disposal of transuranic wastes from military activities is not regulated by NRC; therefore, DOE will implement our requirements for disposal of these transuranic wastes.

The containment requirements in § 191.13 will be applied through design specifications, and the implementing agencies will have to evaluate long-term projections of the disposal system performance. As a result, a vital part of implementation will be the use of adequate models, including the probabilities of unplanned events, to relate appropriate site and engineering data to projected performance. The NRC has made substantial progress in developing such analytical models to predict long-term performance of actual geologic repositories. These models are quite detailed, and they are capable of evaluating how important any uncertainties in specific types of data are to the overall projections of repository performance. Thus, they can provide information about any needs for obtaining better data to determine if repositories meet the containment requirements of these standards.

At our request, the National Academy of Sciences studied the difficulties in verifying compliance with long-term environmental protection requirements for geologic disposal. Our NAS panel developed an approach that specifies the types of information needed and outlines appropriate methods for obtaining this data at prospective sites. Based on this NAS study, NRC's models, our own analytical efforts, and the confidence that should be provided by our assurance requirements, we have concluded that our containment requirements can be effectively implemented.

Effects on Health

A disposal system complying with these standards would confine almost all of the radioactive wastes to the immediate vicinity of the repository for a very long time. Because the wastes would be so well isolated from the environment, any risks to future individuals and populations would be very small.

Potential risks to individuals would depend upon the characteristics of particular disposal sites. However, the following examples are typical of the exposures which individuals in the vicinity of a repository might encounter. After many hundreds or thousands of years, some of the waste may dissolve, be carried by groundwater to nearby aquifers, and flow along those aquifers to surface streams. Individuals using the water from such a stream could receive doses of a few millirem per year. (Even if a person were to ignore available records and sink a water well into an aquifer as close as two kilometers from the repository, projected doses would not be expected to exceed about one rem per year.) Such potential exposures are modest when compared to the approximately 100 millirem per year that everyone continuously receives from natural background radiation. Indeed, in most cases we would expect that any additional exposure would be so small as to be considered trivial to the individuals involved.

With regard to exposures to populations, we estimated the potential long-term health risks to future generations using very general models of environmental transport and the linear, nonthreshold dose-effect relationship that was described earlier. Food chains, ways of life, and the size and geographical distributions of populations will undoubtedly change over a 10,000 year period. Unlike geological processes, factors such as these cannot be usefully predicted over such long periods of time. Thus, in making our health effects projections we found it necessary to depend upon very general models of environmental pathways, and to assume current population distributions and death rates. As a consequence, these projections are intended to be used primarily as a tool for comparing the performance of one waste disposal system to another and for comparison of the risks of waste disposal with those of undisturbed ore bodies. The results of these analyses should not be considered a reliable projection of the "real" or absolute number of health effects resulting from compliance with our standards.

Using our generalized models, we assessed the long-term risk from a repository containing the wastes from 100,000 MTHM—which could include all existing wastes and the future wastes from all currently operating reactors.

We estimate that this quantity of waste, when disposed of in accordance with the proposed standards, could cause no more than 1,000 premature deaths from cancer in the first 10,000 years after disposal: an average of no more than one premature death every 10 years. Any such increase would be far too small to be detectable in any manner compared to today's incidence of cancer, which kills about 350,000 people per year. Similarly, any such increase would be undetectable compared to the approximately 4,000 premature cancer deaths per year that the same linear dose-effect relationship predicts for natural background radiation.

However, although this long-term population risk is clearly very small, the discontinuity between when the wastes are generated and when the projected health effects manifest themselves makes it difficult to determine what level of residual risk should be allowed by these standards. The difficulty arises because most of the benefits derived in the process of waste production fall upon the current generation, while most of the risks fall upon future generations. Thus, a potential problem of intergenerational equity with respect to the distribution of risks and benefits becomes apparent. This problem is sometimes referred to as the intergenerational risk issue, and it is not unique to the disposal of high-level radioactive wastes. If we tried to insure that our standards fully satisfy a criterion of intergenerational equity with respect to the distribution of risks and benefits, it might appear that we should require that no risk be passed on to future generations. This is a condition which we conclude cannot be met by disposal technologies foreseeable within this century. However, there is one particular factor which has reinforced our decision about the reasonableness of the risks permitted under our proposed standards. This is our evaluation of the risks associated with undisturbed uranium ore bodies.

Uranium Ore: Most uranium ore in the United States occurs in permeable geologic strata containing flowing ground water. Radionuclides in the ore, particularly uranium and radium, continuously enter this ground water. We estimated the potential risks from these undisturbed ore bodies using the same generalized environmental models that we used for releases from a waste repository. The effects associated with the amount of ore needed to produce the high-level wastes that would fill the model geologic repository can vary considerably. Part of this variation corresponds to actual differences from one ore body to another; part can be attributed to uncertainties in the assessment. Our estimates ranged from 300 to more than 1,000,000 excess cancer deaths over 10,000 years. Thus, leaving the ore unmined appears to present at least as great a risk to future generations as disposal of the wastes covered by these standards.

We are not sure that this analysis provides an adequate means of resolving the question of intergenerational risk. It has, however, helped to influence our decision of what is an acceptable level of residual risk given our current scientific, technological, and fiscal capabilities. We particularly invite comment upon the questions of intergenerational risk and the acceptability of risk. Additionally, for purposes of comparisons of risks permitted under the standards to radiation risks we are currently exposed to, we have included a brief discussion of the risks from natural background.

Variations in Natural Background: Radionuclides occur naturally in the earth in very large amounts, and are produced in the atmosphere by cosmic radiation. Everyone is exposed to natural background radiation from these natural radionuclides and from direct exposure to cosmic radiation. Individual exposures average about 100 millirem per year, with variations between 60 and 200 millirem/year. These natural background radiation levels have remained relatively constant for a very long time. According to the same linear, nonthreshold dose effect relationship used in our other analyses, an increase of one millirem per year (about one percent) in natural background in the United States would result in about 40 additional deaths per year, or 400,000 over a 10,000 year period.

Regulatory Impact Analysis

This proposed rule was submitted to the Office of Management and Budget (OMB) for review as required by Executive Order 12291. Any comments we received from OMB and our responses to those comments are available for public inspection in the docket cited above under the heading "ADDRESSES."

We have had to take an unusual approach to evaluating the regulatory impact of this proposed action—as required by Executive Order 12291. In most cases, a regulation concerns an ongoing activity and may be considered a burden whose costs should be judged against the regulatory benefits. Here, we could not quantify the costs and benefits of our action compared to the consequences of no regulation because there is no "baseline" program to consider. The appropriate regulations must be established before development of the regulated activity can even begin. Thus, the typical perspectives on costs and benefits are altered. We evaluated how the costs of commercial waste management and disposal might change in response to different levels of protection from our containment requirements and to changes in our assurance requirements.

To evaluate the effects of different levels of protection, we considered the performance of different repository designs in three different geologic media: salt, granite, and basalt. We estimated the costs of the various engineering controls that might be needed to meet different levels, and we made some assumptions about the increased site selection costs that might occur if more stringent standards made it harder to find an adequate site for a repository.

We found that the increased costs of setting the standards at the proposed level could range from zero to 50 million (1981) dollars per year when compared to the costs of choosing a level more than ten times less stringent (release limits ten times greater than our proposed limits). This potential increase is much less than the uncertainty in the total costs for waste management and disposal, which range from about 700 million to almost 1.5 billion (1981) dollar per year. For comparison, electrical utility revenues were about 100 billion dollars in 1980. We estimate that the potential economic impact of choosing the more stringent level of protection could be about a 0.2 percent increase in the costs of generating electricity from nuclear power plants and a much smaller increase (about 0.05 percent) in average electricity rates. The details of these calculations are provided in the report of our regulatory impact analysis.

Alternative Approaches

Besides considering different levels of protection, we also considered several different approaches to our proposed standards. These alternatives are evaluated in our Draft Environmental Impact Statement, and we encourage public comment on these options. We particularly seek comment on a different approach to our standards for disposal (Subpart B)—an alternative that would establish radiation exposure limits for individuals, such as the limit of 25 millirem per year in Subpart A of this proposal, rather than the radionuclide release limits that we are proposing.

Standards based on individual exposure limits, or equivalent standards which limit radionuclide concentrations in air or water, restrict the risks that any particular individual may be exposed to. Particularly when the limits are comparable to or less than natural background levels, they may be more effective at communicating how small the chance of harm from disposal of these wastes should be. However, we chose not to use individual exposure limits in Subpart B because of two unique aspects of these disposal standards:

First, these disposal systems have to protect the environment from these highly concentrated radioactive wastes for much longer than institutional controls can be guaranteed to be effective. Any individual exposure limit we set could only apply at some distance from a repository, or it would have to ignore the risks from unplanned events like inadvertent intrusion—because individuals who fail to understand passive warnings and penetrate directly into or close to a disposal system (through exploratory drilling for water or mineral resources, for example) could receive very large exposures. These exposures would probably exceed any reasonable individual exposure standard.

Second, the disposal standards have to be applied through analytical performance projections—implementing such standards through environmental monitoring and potential remedial actions over thousands of years is not a credible approach. When we compared the analyses needed for compliance with exposure limits to the analyses needed for compliance with release limits, we found that our proposed disposal standards would be much easier to implement than exposure limits. The NRC, which is responsible for applying our standards for high-level waste disposal, made a similar evaluation and also found that standards based on radioactivity release limits could be implemented more readily than standards based on exposures to individuals.

Thus, we believe our proposed approach will facilitate licensing of good disposal systems while providing appropriate environmental protection from the long term risks presented by high-level wastes. However, the arguments favoring individual exposure limits are also persuasive, and we particularly seek comments on which approach we should ultimately select.

Questions for Public Comment

In describing our proposed environmental standards, we have highlighted several issues about which we particularly seek comment. For convenience, we summarize these questions here:

1. Is our definition of high-level waste, which excludes any material with concentrations below the values specified in Table 1, a proper approach to distinguish between wastes which require maximum isolation (as in a geologic repository) and wastes which may be disposed of in less secure facilities?

2. In choosing the proposed level of protection provided by the standards, have we taken an appropriate approach with regard to the long-term residual risks we may pass on to future generations?

3. Have we chose an appropriate approach with regard to the degree of protection that should be anticipated from active and passive institutional controls?

4. Should we adopt our proposed requirement to avoid siting disposal systems where there may be scarce or easily accessible resources—a requirement which could rule out sites which might be advantageous in meeting all of our other requirements?

5. Should we adopt our proposed requirement that recovery of most of the wastes should be feasible if unforeseen events require this in the future—a requirement which might rule out some alternatives to mined geologic disposal?

6. Is our choice of limits on total radioactivity released an appropriate approach to protecting the environment from these long-lived wastes? Or should we develop standards that limit maximum exposures to individuals instead?

List of Subjects in 40 CFR Part 191

Environmental protection, Nuclear energy, Radiation protection, Uranium, Waste treatment and disposal.

Regulatory Flexibility Certification

In accordance with the Regulatory Flexibility Act of 1980, 5 U.S.C. 605(b), the Administrator hereby certifies that this proposed rule would not, if adopted, have any significant impact on small businesses or other entities, and that a Regulatory Flexibility Analysis is not required. The rule woud affect only a small number of facilities, most of which would be operated by the United States Government.

Dated: December 17, 1982.

Anne M. Gorsuch,

Administrator.

A new Part 191 is proposed to be added to Title 40, Code of Federal Regulations, as follows:

SUBCHAPTER F—RADIATION PROTECTION PROGRAMS

PART 191—ENVIRONMENTAL RADIATION PROTECTION STANDARDS FOR MANAGEMENT AND DISPOSAL OF SPENT NUCLEAR FUEL, HIGH-LEVEL AND TRANSURANIC RADIOACTIVE WASTES

Authority: The Atomic Energy Act of 1954, as amended; Reorganization Plan No. 3 of 1970.

Subpart A—Environmental Standards for Management and Storage

§ 191.01 Applicability.

This Subpart applies to radiation doses received by members of the public as a result of the management (except for transportation) and storage of spent nuclear fuel, high-level, or transuranic radioactive wastes, to the extent that these operations are not subject to the provisions of Part 190 of Title 40.

§ 191.02 Definitions.

Unless otherwise indicated in this Subpart, all terms shall have the same meaning as in Subpart A of Part 190.

(a) "Spent nuclear fuel" means any nuclear fuel removed from a nuclear reactor after it has been irradiated.

(b) "High-level radioactive wastes" means any of the following that contain radionuclides in concentrations greater than those identified in Table 1 (Appendix): (1) Liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, in a facility for reprocessing spent nuclear fuels; (2) the concentrated wastes from subsequent extraction cycles, or equivalent; (3) solids into which such liquid wastes have been converted; or (4) spent nuclear fuel if disposed of without reprocessing.

(c) "Transuranic wastes," as used in this Part, means wastes containing more than 100 nanocuries of alpha emitting transuranic isotopes, with half-lives greater than one year, per gram of waste.

(d) "Storage" means placement of radioactive wastes with planned capability to readily retrieve such materials.

(e) "Management and storage" means any activity, operation, or process, except for transportation, conducted to prepare spent nuclear fuel, high-level or transuranic radioactive wastes for storage or disposal, the storage of any of these materials, or activities associated with the disposal of these materials.

(f) "General environment" means the total terrestial, atmospheric, and aquatic environments outside sites within which any operation associated with the management and storage of spent nuclear fuel, high-level or transuranic radioactive wastes is conducted.

(g) "Member of the public" means any individual who is not engaged in operations involving the management, storage, and disposal of materials covered by these standards. A worker so engaged is a member of the public except when on duty at a site.

§ 191.03 Standards for normal operations.

(a) Operations covered by this Subpart should be conducted so as to reduce exposures to members of the public to the extent reasonably achievable, taking into account technical, social, and economic considerations. As an upper limit, except for variances in accordance with 191.04, these operations shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public due to: (1) Operations covered by Part 190, (2) planned discharges of radioactive material to the general environment from operations covered by this Subpart, and (3) direct radiation from these operations; shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, or 25 millirems to any other organ.

§ 191.04 Variances for unusual operations.

(a) The implementing agency may grant a variance temporarily authorizing operations which exceed the Standards specified in 191.03 when abnormal operating conditions exist if: (1) A written request justifying continued operation has been submitted, (2) the costs and benefits of continued operation have been considered to the extent possible, (3) the alternatives to continued operation have been considered, and (4) continued operation is deemed to be in the public interest.

(b) Before the variance is granted, the implementing agency shall announce, by publication in the *Federal Register* and by letter to the governors of affected States: (1) The nature of the abnormal operating conditions, (2) the degree to which continued operation is expected to result in doses exceeding the standards, (3) the proposed schedule for achieving conformance with the standards, and (4) the action planned by the implementing agency.

§ 191.05 Effective date.

The standards in this Subpart shall be effective 12 months from the promulgation date of this rule.

Subpart B—Environmental Standards for Disposal

§ 191.11 Applicability.

This Subpart applies to radioactive materials released into the accessible environment as a result of the disposal of high-level or transuranic radioactive wastes, including the disposal of spent nuclear fuel. This Subpart does not apply to disposal directly into the oceans or ocean sediments.

§ 191.12 Definitions.

Unless otherwise indicated in this Subpart, all terms shall have the same meaning as in Subpart A of this Part.

(a) "Disposal" means isolation of radioactive wastes with no intent to recover them.

(b) "Barriers" means any materials or structures that prevent or substantially delay movement of the radioactive wastes toward the accessible environment.

(c) "Disposal system" means any combination of engineered and natural barriers that contains radioactive wastes after disposal.

(d) "Groundwater" means water below the land surface in a zone of saturation.

(e) "Lithosphere" means the solid part of the Earth, including any groundwater contained within it.

(f) "Accessible environment" includes: (1) The atmosphere, (2) land surfaces, (3) surface waters, (4) oceans, and (5) parts of the lithosphere that are more than ten kilometers in any direction from the original location of any of the radioactive wastes in a disposal system.

(g) "Reasonably foreseeable releases" means releases of radioactive wastes to the accessible environment that are estimated to have more than one chance in 100 of occurring within 10,000 years.

(h) "Very unlikely releases" means releases of radioactive wastes to the accessible environment that are estimated to have between one chance in 100 and one chance in 10,000 of occurring within 10,000 years.

(i) "Performance assessment" means an analysis which identifies those events and processes which might affect the disposal system, examines their effects upon its barriers, and estimates the probabilities and consequences of the events. The analysis need not evaluate risks from all identified events. However, it should provide a reasonable expectation that the risks from events not evaluated are small in comparison to the risks which are estimated in the analysis.

(j) "Active institutional controls" means: (1) Guarding a disposal site, or (2) performing maintenance operations or remedial actions at a disposal site, or (3) controlling or cleaning up releases from a disposal site.

(k) "Passive institutional controls" means: (1) Permanent markers placed at a disposal site, (2) public records or archives, (3) Federal Government ownership or control of land use, or (4) other methods of preserving knowledge about the location, design, or contents of a disposal system.

(l) "Heavy metal" means all uranium, plutonium, or thorium placed into a nuclear reactor.

§ 191.13 Containment requirements.

Disposal systems for high-level or transuranic wastes shall be designed to provide a reasonable expectation that for 10,000 years after disposal:

(a) Reasonably foreseeable releases of waste to the accessible environment are projected to be less than the quantities calculated accoring to Table 2 (Appendix).

(b) Very unlikely releases of waste to the accessible environment are projected to be less than ten times the quantities calculated according to Table 2 (Appendix).

§ 191.14 Assurance requirements.

To provide the confidence needed for compliance with the containment requirements of § 191.13, disposal of high-level or transuranic wastes shall be conducted in accordance with the following requirements:

(a) Wastes shall be disposed of promptly once disposal systems are available and the wastes have been suitably conditioned for disposal.

(b) Disposal systems shall be selected and designed to keep releases to the accessible environment as small as reasonably achievable, taking into account technical, social, and economic considerations.

(c) Disposal systems shall use several different types of barriers to isolate the wastes from the accessible environment. Both engineered and natural barriers shall be included. Each such barrier shall separately be designed to provide substantial isolation.

(d) Disposal systems shall not rely upon active institutional controls to isolate the wastes beyond a reasonable period of time (e.g., a few hundred years) after disposal of the wastes.

(e) Disposal systems shall be identified by the most permanent markers and records practicable to indicate the dangers of the wastes and their location.

(f) Disposal systems shall not be located where there has been mining for resources or where there is a reasonable expectation of exploration for scarce or easily accessible resources in the future. Furthermore, disposal systems shall not be located where there is a significant concentration of any material which is not widely available from other sources.

(g) Disposal systems shall be selected so that removal of most of the wastes is not precluded for a reasonable period of time after disposal.

§ 191.15 Procedural requirements.

Performance assessments to determine compliance with the containment requirements of § 191.13 shall be conducted in accordance with the following:

(a) The assessments shall consider realistic projections of the protection provided by all of the engineered and natural barriers of a disposal system.

(b) The assessments shall not assume that active institutional controls can prevent or reduce releases to the accessible environment beyond a reasonable period (e.g., a few hundred years) after disposal. However, it should be assumed that the Federal Government is committed to retaining passive institutional control of disposal sites in perpetuity. Such passive controls should be effective in deterring systematic or persistent exploitation of a disposal site, and it should be assumed that they can keep the chance of inadvertent human intrusion very small as long as the Federal Government retains such passive control of disposal sites.

(c) The assessments shall use information regarding the likelihood of human intrusion, and all other unplanned events that may cause releases to the accessible environment, as determined by the implementing agency for each particular disposal site.

§ 191.16 Effective date.

The standards in this Subpart shall be effective immediately upon promulgation of this rule; however, this Subpart does not apply to wastes disposed of before promulgation of this rule.

Appendix

TABLE 1.—CONCENTRATIONS IDENTIFYING HIGH-LEVEL RADIOACTIVE WASTES

Radionuclide	Concentration (curies per gram of waste)
Carbon-14	4x10[illegible]
Cesium-135	5x10[illegible]
Cesium-137	5x10[illegible]
Plutonium-241	2x10[illegible]
Strontium-90	7x10[illegible]
Technetium-99	2x10[illegible]
Tin-126	7x10[illegible]
Any alpha-emitting transuranic radionuclide with a half-life greater than 20 years	1x10⁻⁷
Any other radionuclide with a half-life greater than 20 years	1x10[illegible]

NOTE.—In cases where a waste contains a mixture of radionuclides, it shall be considered a high-level radioactive waste if the sum of the ratios of the radionuclide concentration in the waste to the concentration in Table 1 exceeds one.

For example, if a waste containing radionuclides A, B, and C in concentrations C_a, C_b, and C_c, and if the concentration limits from Table 1 are CL_a, CL_b, and CL_c, then the waste shall be considered high-level radioactive waste if the following relationship exists:

$$\frac{C_a}{CL_a} + \frac{C_b}{CL_b} + \frac{C_c}{CL_c} > 1$$

TABLE 2.—RELEASE LIMITS FOR CONTAINMENT REQUIREMENTS

(Cumulative Releases to the Accessible Environment for 10,000 Years After Disposal)

Radionuclide	Release Limit (curies per 1000 MTHM)
Americium-241	10
Americium-243	4
Carbon-14	200
Cesium-135	2000
Cesium-137	500
Neptunium-237	20
Plutonium-238	400
Plutonium-239	100
Plutonium-240	100
Plutonium-242	100
Radium-226	3
Strontium-90	80
Technetium-99	10000
Tin-126	30
Any other alpha-emitting radionuclide	10
Any other radionuclide which does not emit alpha particles	500

Note 1.—The *Release Limits* in Table 2 apply either to the amount of high-level wastes generated from 1,000 metric tons of heavy metal (MTHM), or to an amount of transuranic (TRU) wastes containing one million curies of alpha-emitting transuranic radionuclides. To develop *Release Limits* for a particular disposal system, the quantities in Table 2 shall be adjusted for the amount of wastes included in the disposal system. For example:

(a) If a particular disposal system contained the high-level wastes from 50,000 MTHM, the Release Limits for that system would be the quantities in Table 2 multiplied by 50 (50,000 MTHM divided by 1,000 MTHM).

(b) If a particular disposal system contained five million curies of alpha-emitting transuranic wastes, the Release Limits for that system would be the quantities in Table 2 multiplied by five (five million curies divided by one million curies).

(c) If a particular disposal system contained both the high-level wastes from 50,000 MTHM *and* 5 million curies of alpha-emitting transuranic wastes, the Release Limits for that system would be the quantities in Table 2 multiplied by 55:

$$\frac{50{,}000\ \text{MTHM}}{1{,}000\ \text{MTHM}} + \frac{5{,}000{,}000\ \text{curies TRU}}{1{,}000{,}000\ \text{curies TRU}} = 55$$

Note 2.—In cases where a mixture of radionuclides is projected to be released, the limiting values shall be determined as follows: For each radionuclide in the mixture, determine the ratio between the cumulative release quantity projected over 10,000 years and the limit for that radionuclide as determined from Table 2 and Note 1. The sum of such ratios for all the radionuclides in the mixture may not exceed one.

For example, if radionuclides A, B, and C are projected to be released in amounts Q_a, Q_b, and Q_c, and if the applicable Release Limits are RL_a, RL_b, and RL_c, then the cumulative releases over 10,000 years shall be limited so that the following relationship exists:

$$\frac{Q_a}{RL_a} + \frac{Q_b}{RL_b} + \frac{Q_c}{RL_c} < 1$$

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APPENDIX C

REFERENCES

Following is a listing of the documents considered by the High-Level Radioactive Waste Subcommittee in the course of its review of EPA's proposed standards for the disposal of high-level radioactive wastes. The list is divided into three parts. The first includes those EPA documents which were used as references, the second other documents used as references, and the third, documents which were provided but not used as references. The list does not include numerous minor documents handed out at Subcommittee meetings which are a part of the minutes of those meetings.

1. EPA Documents Used as References

Alternative Disposal Concepts for High-Level and Transuranic Radioactive Waste Disposal, U.S. EPA, ORP/CSD-79-1, May 1979.

A Review of Radiation Exposure Estimates from Normal Operations in the Management and Disposal of High-Level Radioactive Wastes and Spent Fuel, EPA 520/3-80-008, August 1980.

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Potential Individual Doses from Disposal of High-Level Radioactive Wastes in Geologic Repositories (Draft), EPA 520/1-82-026, January 1983.

Radiation Exposure From Solidification Processes for High-Level Radioactive Liquid Wastes, EPA 520/3-80-007, May 1980.

Technical Support of Standards for High-Level Radioactive Waste Management, Volume A--Source Term Characterization, EPA 520/4-79-007, July 1977.

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P.O. Box 5890 **Albuquerque, New Mexico 87185**

January 30, 1984

Dr. Herman Collier
President
Moravian College
Main and Elizabeth Avenues
Bethlehem, PA 18018

Dear Herman:

I have reviewed the revised draft of the Executive Summary of the report of the High-Level Radioactive Waste Disposal Subcommittee of the Executive Committee of the EPA Science Advisory Board. Although I am in general agreement with the findings and recommendations of the Subcommittee, I am concerned that the manner in which they are presented may diminish the potential for their being accepted.

The specific issue of concern relates to the evolving concepts of risk assessment and risk management. At the time your Subcommittee started its review, the distinction between risk assessment and risk management was not drawn as sharply as it is now. In addition, the Subcommittee was provided review material which blended risk assessment and risk management issue. That this was the case is evidenced by the fact that you were presented with a proposed standard for review. This blending of risk assessment and risk management has been extended into your subcommittee's Executive Summary which concerns me as I will detail below.

Although the Summary highlights a number of important findings and recommendations, it is my impression that two findings stand out as being of major importance. The first finding is that conservative assumtpions have been used to link releases and health risks resulting in an over-estimation of health risks by an order of magnitude or so for a given level of release. This is an important matter of scientific judgement and within the context of recent usage of the term is a "risk assessment" matter. The bottom line conclusion that may be drawn from this "risk assessment" finding is that the release limits in Table 2 of the

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proposed standard should be increased by a factor of 10 for most radionuclides if the societal risk objective is held constant. This conclusion deserves a statement on its own.

A second finding is that the proposed societal objective of not exceeding 1000 deaths in 10,000 years is considerably more stringent than those generally required or adopted in today's society. The conclusion as to stringency compared to other sources of risk is a matter of scientific judgement as I will discuss later. However, the recommendation to relax the societal objective is a matter of risk management. Unfortunately, the summary weaves all of what I have discussed above into a single recommendation.

Certainly the Subcommittee members, as informed members of the public, should feel free to offer their opinion that the "risk management" judgement of not exceeding 1000 deaths in 10,000 years is too conservative. However, in offering comments on this aspect of the standard, their comments should carry no more or no less weight than that of any other member of society. By bringing together in one recommendation a risk assessment issue (relaxation of the release limits) and a risk management issue (relaxation of the societal objective), they raise the possibility that their scientific judgement will not be heeded.

Having noted the need to separate, to the extent it is feasible, risk assessment and risk management issues, I should hasten to add that I do believe it is appropriate for scientists with information on comparative risks to call this information to the attention of decision makers who must ultimately make risk management decisions, i.e., set standards. In this regard, I am pleased that the Subcommittee has included in their report comparative information on several sources of risk. Recognizing the degree to which Society controls or accepts other risks and considering a background rate of about 400,000 cancer deaths per year, it is difficult to even comprehend a societal objective of 0.1 deaths per year (or 1000 deaths in 10,000 years). As a scientist/citizen, it is this comparative risk information that leads me to the opinion that the societal objective can probably be relaxed, and perhaps very substantially, dependent upon the cost of achieving it as well as other social and policital factors.

I would be pleased to meet with Mr. William Ruckelshaus, other EPA officials, you, your subcommittee or other members of the Science Advisory Board if the position I have stated needs further elaboration.

Sincerely,

Roger

Roger O. McClellan, D.V.M.
Director

ROM:mm

xc: Dr. Norton Nelson
Dr. Terry Yosie